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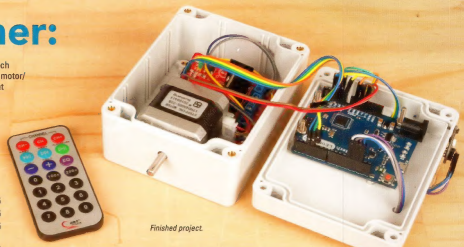

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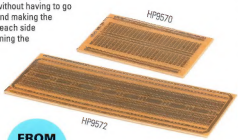

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Subscription rates: $105.00 per year, post paid, in Australia.
For overseas rates, see our website or email silicon@siliconchip.com.au

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ISSN 1030-2662

* Recommended & maximum price only.

Printing and Distribution:
bluestar
Derby Street, Silverwater, NSW 2148.

Editorial Viewpoint

Are electronic medical records privacy concerns overblown?

Around one million Australians have decided to opt out of the Australian Government "My Health Record" electronic medical records scheme.

While I am glad that we have that option, I do not believe opting out is a wise decision. The potential benefits of having an electronic medical record far outweigh any privacy concerns, especially for older people or those with chronic conditions.

If you have spent much time in a hospital, you will know that before treating you, they ask a series of questions about what medical conditions you have, whether you have any allergies, any recent medical treatments, what medications you are on and so on. For those with a long history (eg, if you have a serious condition), this can take some time.

It's pretty clear that our doctors, nurses and hospitals are overworked, as demonstrated by the long waiting times in emergency departments and the difficulty of booking an appointment with a GP. So it seems like a waste of time asking these questions again and again if they could just look up your medical record and have it all right in front of them.

Electronic medical records would also reduce the potential for mistakes and improve the accuracy of diagnoses. When giving them an oral history, you may forget to tell them some things, misremember others and there may even be details that your doctor didn't tell you previously which could be important.

This is especially true if you are so ill that you cannot think or speak clearly or are unconscious. I would think that anyone who is seriously ill would want the doctors and nurses treating them to have full access to their medical history, for the best chance of a speedy recovery.

So I believe it's clear that a well-implemented electronic medical record scheme would have significant benefits both in improving the efficiency of our healthcare system as well as providing better outcomes for patients. As for the downsides, I can think of two.

The first one is that more medical staff would have access to your records so that a "bad apple" working in the medical industry would have greater scope for mischief. Secondly, the electronic record storage system must be implemented in a very secure manner so that hackers cannot gain access to private data.

Based on the many recent stories of data breaches, it is clear that providing this level of security is not easy. But I believe it is possible, and given the bad publicity that would surround such a data breach, I hope that our Government is taking all the necessary steps to keep these records secure.

Ultimately, you have to consider the risks versus the rewards. Even if someone who should not have access to your medical records did gain access, how would that impact you? Are they really going to be able to blackmail or embarrass you over it? In most cases, I doubt it. However, if a doctor urgently needs your medical details and cannot get them, that could be a disaster.

Admittedly, only a small percentage of people will end up in that position but I believe an even smaller percentage will face negative consequences from a data breach.

So I suggest if you have opted out of this electronic medical records system (or are about to do so) that you should think carefully about whether that decision is or was really in your best interests.

Nicholas Vinen

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Further discussion on correct mains Earthing

Ray Smith's letter regarding MEN connections and switchboard wiring on page 8 of the August 2018 issue seems to have caused some confusion in later Mailbag letters.

The photo published along with the letter is described as Ray Smith's "home switchboard", not the installation where he tripped an RCD breaker.

The photo is typical of a domestic main switchboard. My understanding is the MEN link is created at the main switchboard. The main earthing conductor runs unbroken from the Earth electrode directly to the Neutral link as per the photo.

Outgoing Earths (lighting, power etc) are bonded to the main Earth cable (not visible in photo) either by soldering or an approved connector.

If an outbuilding has a sub-board fed from the main switchboard and the supply cable has an included Earth, then another MEN link and Earth electrode are not required at the sub-board. The associated Earths at the sub-board are bonded together with the sub-board supply cable Earth.

The exception is if the sub-board is supplied from an aerial cable (no included Earth). Then, the sub-board is treated as a main switchboard, requiring an Earth electrode and MEN link.

As for RCDs tripping, it is not uncommon for upstream RCDs to trip when working on de-energised circuits. It does not necessarily mean a wiring fault. Stray noise on de-energised circuits can be enough to trip RCDs if Earth and Neutral conductors are flashed together.

I am a retired electrician with a mining background. It's possible that the situation has changed since I was working in the field but even if that's the case, many installations like this one will still be in use today. One reason for changes in the relevant standards may be the introduction of Earth loop impedance testing.

Allan Doust,
Erskine, WA.

Incorrect description of 6AV6 valve diode function

The Vintage Radio article on the Ekco receiver in the September 2018 issue of Silicon Chip (**siliconchip.com.au/Article/11241**) states that the diode connected via pin 5 of the 6AV6 valve does nothing.

This is not correct. It is not simply used as a connection point; the diode functions as a clamp across the AGC line to prevent it ever going positive.

In some other designs, this diode may be fed a small positive voltage through a high-value resistor. This is to keep it in conduction, delaying the AGC action until the negative voltage from the AGC rectifier increases to the point where it overcomes the positive voltage.

In the Ekco Gondola circuit, the AGC line is fed through an unusually high-value resistor (R8, 5.6MΩ) and there is no fixed or cathode bias applied to the 6BE6 or 6BA6. So under no signal conditions, the valves are running without any negative bias until a station is tuned in and the AGC voltage is produced.

This saves components and I expect that the designer thought that the set would spend most of its life tuned to a station and that in practice the no-bias condition would be infrequent and not a problem. The high-value feed resistor and the possibility of grid currents flowing make the inclusion of the clamp diode a wise choice.

In fact, while most people who have some experience with valves would think this is not possible, given the high voltage drop in valve rectifiers (eg, 6X4, 5AR4 etc), a valve diode working at very low currents (in the microamp range) will have a very low forward voltage.

To back up this statement, I have been looking through various data sheets for the 6AV6 to find some actual figures.

However, none of the manufacturers seem to show the information expressed in the way needed, so I thought that I would make my own measurements using a random 6AV6, resistor, power supply and a couple of digital multimeters.

Some of the forward voltage figures I obtained were 115mV at 20μA, 315mV at 40μA, 415mv at 50μA and 858mV at 100μA.

These figures were obtained with a good, used valve and were slightly lower with a brand new valve under the same conditions. They are in line with what I expected.

Clearly, when used in a detector application, you would not want a high voltage drop across the diode. At these voltages and currents, the diode in question would not have a problem clamping the AGC line if a positive voltage occurred.

But that is not the end of the story! After removing the DC power supply connection (with the heater still energised), the voltage across the diode changed polarity and rose to just over -600mV; suddenly, the penny dropped! This was the measurement of the diode contact potential. It would typically be around -1V but the 10MΩ input resistance of the DVM I was using was loading it.

Substituting another multimeter with an input resistance of 100MΩ increased the reading to over -800mV, as expected.

Going back to the Ekco circuit, without a signal tuned in and hence no AGC voltage present, the diode contact potential is present on the AGC line and thus provides a level of reduced negative bias for the 6BE6 and 6BA6 valves; this would result in them not being run under zero bias conditions.

When a station is tuned in, the AGC voltage rises and provides normal operating conditions. I suspect that the high value for R8, in series with R4 and R5, was chosen to place minimal load on the diode in an effort to keep the contact potential as high as possible.

A side effect of this is the rather long

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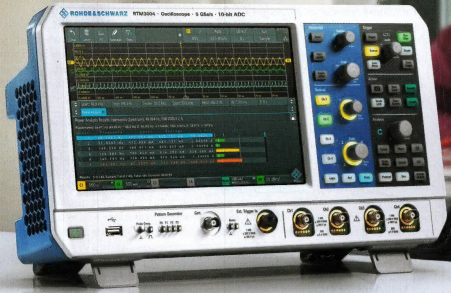

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AGC time constant and one wonders why the value of C1 was not reduced; maybe the effect was not noticeable.

I have seen this approach used in other circuits, such as the UK-made Pilot "Little Maestro" and the American Admiral 7T10. I don't recall seeing the use of the diode in this way in other Australian sets but I am sure that there is one out there somewhere. Astor did make use of a diode in the same position in their model JPP Radiogram but it was forward-biased to provide delayed AGC.

So the second diode of the 6AV6 actually has two functions (or possibly three in other designs).

Warwick Woods,
Glen Iris, Vic.

Comment: Thanks for your thorough explanation of the second diode in the 6AV6 of the Ekco Gondola circuit. The concept of using it as a clamp diode never occurred to us and if it had been suggested, we would have poo-pooed it.

If you do an internet search for "forward voltage drop of thermionic diode" is it clear that most writers think that thermionic diodes have the same forward voltage drop and "knee" characteristic as silicon diodes – which is absolute rubbish.

In fact, it was well known that if you substituted silicon rectifier diodes for a valve rectifier, the resultant DC voltage was much higher. For example, it could be as much as 50V higher for a 285V power supply rail. Nor could valve rectifiers be used for low voltage supplies; selenium rectifiers were used instead.

So in our defence, we would not have entertained the concept of using a thermionic detector as a clamp diode; how wrong we were!

This is yet another demonstration of the ingenuity of those old-time valve circuit designers. Using what we would now regard as primitive technology, they managed to produce very clever designs with a low component count. And they managed it without all the fancy measurement equipment we have available to us today.

Suggestions wanted for good free ECAD software

Hello, I am wondering if you can recommend any good freeware PCB/schematic design software. I just downloaded and installed KiCad but it's a huge program and it looks like it's difficult to use. I want something more basic that will let me design PCBs and schematics quickly and easily. I don't need multi-layer board support or a million pins, just single or double-sided PCB design.

I would like to use software that meets the following criteria:

- Freeware (no restrictions on use)
- Easy-to-use
- Not tied to a PCB manufacturer
- Not cloud-based
- Reasonable download size (and preferably portable so that it can be installed on a USB flash drive)
- Works with standard formats such as Gerber files
- Able to run on older versions of Windows, like XP
- Works on a variety of screen sizes and resolutions

Bruce Pierson,
Dundathu, Qld.

Comment: while we have limited experience with KiCad, it does seem to have quite a steep learning curve. While there are many different ECAD packages available, we have not conducted an exhaustive survey.

We use Altium; the same company also makes the free CircuitMaker software and we think it would meet most or all of your criteria, so you should try it.

Some free software that might be worth a look include www.freepcb.com or opencircuitdesign.com

There is also a list on wikipedia of free design software: siliconchip.com.au/link/aalt

Our readers may be able to help you with suggestions of other software to try.

Available internet bandwidth is not sufficient for streaming

I read with interest your September editorial, and while I agree in general terms with your conclusions, I feel that it is necessary to point out several problems with the future you are predicting. These do not mean it won't happen, just that if and when it does, there will be problems you have not covered.

The elephant in the room is the assumption that all consumers will have access to a broadband internet connection whose costs and data allowance allow unfettered streaming. This is most certainly not the case today and seems unlikely to apply to all or nearly all consumers for decades if ever.

For a start, the NBN rollout will not be completed for at least another couple of years, and this will leave three classes of customers for which this does not apply. These are satellite customers, wireless customers and customers that cannot be serviced.

This last category would be very small, as it would apply only to those premises that are in a position where not even satellite can work (shadow of trees, buildings, mountains etc) – satellite is being used to service difficult premises, including some actually in capital cities.

Satellite and wireless capacity is constrained by available bandwidth, with wireless capacity being, at least in theory greater. Actual available bandwidth for satellite is explicitly limited for customers by NBN Co and wireless is also theoretically limited by NBN Co. In practice there seem to be numerous accounts of bandwidth limitations happening well below these limits by too many subscribers on particular sectors of a particular tower.

In the case of satellite, I have had demonstrated in my own home that four children, armed with laptops, tablets and phones, are quite capable of using a month's data allowance (close to the maximum allowed by NBN) in less than 24 hours, simply by streaming.

It needs to be realised that a household with, for example, two adults and two children, may well be wanting to view four different streaming services in the same peak hour. This will strain even some of NBN's hard-wired services, especially fibre to the node ones, and is essentially impractical for either wireless or satellite.

Even apart from data allowance issues, in the scenario you picture, not only would this be happening in our example household, but also in most of the other ones connecting to that wireless tower or satellite beam at that peak hour.

The same problems exist if you use the argument "A lot of them can or will be using their mobile phones". For a start, it is costly to use this amount of data, and even apart from the cost, the bandwidth from individual towers will still come into play.

And there is only so much electromagnetic spectrum; despite new technology such as 5G boasting much higher speeds, for the reasons mentioned above, as soon as you have multiple

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users on the one tower the speed for each user drops.

This development will widen the city-country gap, but there will be some (probably very vocal) unhappy campers in the cities as well. Ultimately this is going to lead to social problems, and likely a backlash against those seen as responsible, probably including telcos, media, and governments.

And no, I don't have a solution, but I do feel that if you are talking about a Brave New World, perhaps some discussion about those who will miss out is in order. And as high resolution and ultra-high resolution video become normal, the whole situation is going to get a lot worse.

John Denham,
Elong Elong, NSW.

Nicholas responds: you are right that streaming is less practical for those without fixed line internet. But the available bandwidth and data allowances have been increasing each year. Fixed-line plans with no data limit are now quite common and affordable while data via mobile and satellite internet connections are becoming increasingly cheap.

Unlimited NBN plans can be found at around $70/month (which is what I am currently paying for unlimited ADSL2 including line rental). Just a few years ago, a mobile data plan with more than a couple of gigabytes of data was really expensive. You can now get a 45GB mobile data plan for $15.

NBN satellite can now be had with quotas up to 450GB. That's enough to stream 1080p video for an average of at least eight hours per day.

Australians had a total of 9.1 million online streaming subscriptions as of the end of July (see siliconchip.com.au/link/aalu). That doesn't include streaming from free services like ABC iView, SBS On Demand, YouTube and so on. Our networks seem to be coping with all this streaming just fine!

I see no reason to believe that if streaming becomes even more popular, the network bandwidth and quotas cannot increase to cope with it.

Our office is now running on an NBN FTTN (Fibre to the Node) connection with over ten times the bandwidth I have on my home ADSL connection and yet I can stream 1080p video at home without any problems.

So I doubt NBN fixed line customers will have any problem streaming multiple videos in the same household as long as they select an appropriate plan.

Sure, streaming 4K content takes more bandwidth but it's hardly a disaster if you are "downgraded" to 1080p when too many people are trying to stream video at the same time. Many people would not even notice the difference. And don't forget that more efficient video codecs are being released over time which should reduce the bandwidth required for UHD content.

In summary, I have faith that the marketplace to deliver increased aggregate internet bandwidth as consumers demand it. And I think they will demand it once they become familiar with the benefits of video streaming compared to the traditional broadcast system.

Why don't DMMs test zener diodes?

Why after all these years do the manufacturers of DMMs, from cheap to expensive, forget to include a zener diode test function? I wouldn't even mind if I had to buy an optional plug-in module. I use zener diodes frequently in my projects and they are mostly cannibalised from other circuits, so I need to test them quite regularly.

Please design a simple plug-in module tester, or a miniaturised module independently powered say by lithium coin cells, with an LED voltage display. I'm sure that some manufacturers would get the hint! I and no doubt many other readers would be very grateful. Keep up the great work at SILICON CHIP; your efforts are most appreciated.

Colin O'Donnell,
Adelaide, SA.

Comment: manufacturers might see it as a significant increase in complexity when designing their product, for a feature that might not be that popular.

Jaycar used to sell a DMM with a zener diode test facility, Cat QM1292 (Protek 608) but it has been discontinued. We bought one and while quite expensive, it is accurate and has some great features, including the zener diode test. It will only go up to about 20V but that still covers the majority of devices that we need to test.

And since its test function is limited to 1mA, it's also good for testing LEDs, getting an idea of their brightness and so on.

We published a comprehensive zener diode tester design in the Novem-

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ber 2011 issue (siliconchip.com.au/Article/1219), which handles devices rated up to 100V but it doesn't have a display and instead plugs into a standard DMM acting as a voltmeter.

The PCB for that project is available from our Online Shop (siliconchip.com.au/Shop/8/696).

Praise for simple power monitoring solutions

I would like to comment on Walter Hill's letter in the Mailbag section of the August 2018 issue, titled "Monitoring home electricity usage" (page 6).

I have used the Efergy system with good success, although you need to be aware of the limitations of the Efergy system (and other budget-priced home consumption indicators). Because the Efergy uses a current transformer without monitoring the supply voltage, it displays VA used rather than watts consumed.

This is because these systems have no way to measure the phase angle between the voltage and the current to determine the power factor of the measured circuit:

power (W) = volts × amps (VA) × power factor (PF)

All the cheap monitoring systems take no account of the power factor of the circuit, so their readings almost always differ from meter readings. The supply meter reading takes into account the power factor, measuring true power in watts.

A resistive device like a space heater will have a power factor of one where the VA measurement equals watts. In this case, the Efergy system will be accurate.

Most other appliances will have a power factor less than one and so the VA reading will be higher than the watts reading shown on the supply meter. For example, this applies to appliances with motors, fluorescent lighting, LED lighting, computers, televisions and so on. In this case, Efergy will give readings higher than the actual consumption.

Budget monitoring systems are available which monitor the flashing red light on your supply meter (which flashes each time a certain number of watts have been consumed) and are more accurate, but are limited to measuring the total supply for the house and not individual circuits.

Efergy also has an option which allows you to record VA used during different preset time periods, so that (for example) if you are billed on a single rate tariff, you can see if you would be better off on a time-of-use tariff. The free Efergy software even lets you use this data to compare the offerings of several suppliers.

In this case, it does not matter that it measures VA rather than watts because the comparison of tariffs and suppliers is all relative.

The output from the solar inverter would be a modified square wave so I imagine the output of the low-end Efergy CT would not be entirely accurate in that situation.

I am aware of several cases where the Efergy software has led to substantial savings on electricity accounts, by changing to a time-of-use tariff. Consumers often focus on the higher cost of the peak rate without considering the extended hours of the cheap off-peak rate (all weekend in some areas).

Without a system like the Efergy one, you cannot make a realistic comparison of tariffs because it is next to impossible to figure out when electricity is being used.

By the way, I am not associated in any way with Efergy. But I find their system useful, keeping in mind its limitations.

John Lean
Orange, NSW.

Deficiencies of Smart TVs

I would like to make some comments on a similar topic to your editorial in the September 2018 issue, regarding the idea that video streaming over the internet could take over from broadcast TV.

The "flavour of the month" between 3D TV and 4K was "Smart" TVs with built-in web access that allows direct streaming of TV shows, both current and past.

We've been watching a fair number of streamed videos recently (for my wife mostly) using a Toshiba laptop, which is OK as far as it goes. But the lack of normal a remote control was a problem, as she's not terribly computer literate and I was continually being called back to drive it.

I don't really want to shell out for a proper Smart TV as I already have a number of perfectly good LCD sets, so I thought a set-top box might be the go. I don't know why they're called that; most TVs don't have space for a box to sit on top!

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I originally tried a "Kodi Box" I bought online but it was very erratic in operation and the supplied remote control was terrible. Eventually, it died and I dropped the matter for a while.

Then I saw that JB HiFi had the "Sony BDP-S3500 Blu-ray Player with Wi-Fi " on sale for $118, which can "Stream Entertainment wirelessly for enjoyment of diverse full HD online content".

A "reasonable person" (as defined under Australian Consumer Law) would surely interpret that as meaning that you would be able to stream all the popular main network services, ie, Freeview Plus (SBS on Demand, ABC iView, TenPlay, 9Now and 7Plus) as well as Netflix, Stan and any of the other subscription services.

Alas, when I fired it up, what I was presented with was a selection of useless streaming services I've never heard of plus a rudimentary web browser, plus support for Netflix, YouTube, SBS on Demand, ABC iView and TenPlay.

To cut a long story short; SBS on Demand, ABC iView and TenPlay all worked a treat (considerably better than the laptop) and with a reasonable remote control. My wife got the hang of it almost instantly and was soon firing it up herself and binging to her heart's content.

So what about 7Plus and 9Now? With your PC or phone, it's just a matter of locating and installing the correct software. Not so this product! A quick Google search revealed many people asking the same question. The answer from Sony was inevitably "You can't...."

The only way the relevant apps can be installed is as part of an online software upgrade from the Sony website, if the service provider has seen fit to make them available and if Sony sees fit to add them!

I asked 7Plus and 9Now about this and they blithely confirmed that there are many platforms that they have either not gotten round to, or have no intention of providing for!

So it's nowhere near as clear-cut as most people have been led to imagine. Basically, if you have a PC, anything goes; otherwise, do your research before pledging your plastic!

Keith Walters,
Riverstone, NSW.

Nicholas comments: you are right that if you buy a "Smart" TV or any other product with the intention of using it for streaming, you should do your homework and find out exactly which services it supports before you make the purchase.

As you have discovered, many products do a less than stellar job (to put it mildly). LG and Samsung seem to be among the better manufacturers in this regard.

We have an LG TV that I bought around two years ago and we have been delighted with its features. It runs Open webOS which has support for DLNA (LAN streaming), YouTube, Netflix, Stan, Amazon Prime, Freeview Plus and more.

It also has a convenient inbuilt digital video recorder (DVR) with support for internal memory and external USB storage devices including a hard drive. Overall, it makes for a very slick viewing experience.

My only real complaints are that the Freeview apps are a bit glitchy, especially when used with a slower internet connection, and navigation can be difficult. But I believe the former is mainly the fault of the networks, and the latter may be (at least partially) problems at their end as well.

1970s Auditec amplifier circuit diagrams wanted

I would like to get schematics for Auditec amplifiers that were made in Australia in the 1970s. I have acquired 300W per channel and 100W per channel amplifiers and would like to have a copy of the schematics to go along with them.

While reading the October 2010 article about designing and installing a hearing loop for the deaf (siliconchip.com.au/Series/11), that the amplifier shown is the same brand as the ones I have except mine are out of a cinema. So I thought you might be able to help. I tried contacting Auditec (yes, they are still around) but they were not able to help.

Leon Kyle,
Wanganui, NZ.

Solving Water Tank Level Meter min/max problem

I just read the letter from K. G., of One Tree Hill, SA in the Ask Silicon Chip section of the October 2018 issue (page 108). He had a problem with the Water Tank Level Meter calibration, which reminded me of a similar problem I experienced when I built my unit about six months ago.

My unit initially refused to detect that the tank was 100% full even though it clearly was. I think his problem may be different as that unit was able to determine the maximum level in a different tank.

My problem was that after building the unit and turning it on for the first time (without the pressure sensor connected, as I was just testing at that stage), the maximum raw tank level was set by the software to 65535. This figure remained despite connecting the sensor and power cycling the unit several times and waiting several hours between resets.

To re-calibrate the unit, the article suggests running a wire link from pin 15 of the ESP8266 to 3.3V and pressing the reset button. Even with the sensor connected, this did not work for me and the maximum raw level remained at 65535.

I did manage to eventually get the unit working correctly by replacing the wire link with a toggle switch and leaving it in the on position for some time while the unit was running.

I allowed a couple of hours to ensure the software cycled through a number of times before returning the switch to the off position.

I have not tried to work out how the software works but I believe it should set the maximum raw level to zero after a calibration reset or reload but instead sets it to or leaves it at 65535.

If I have to reload the software at some stage in the future, I'll hard-code the maximum and minimum levels as you suggested, but I would be interested to know if there is a problem with the original code.

Tony Lohrey,
Launceston, Tas.

Comment: we checked the code when we wrote the response to K. G. last month and could not find any problems with the calibration or reset logic and those were both tested on our prototype before publication.

That unit remained in service for around a year before rainwater ingress damaged it and there were no problems with the minimum/maximum level calibration either when first installed or later on during that time.

We wonder if changes to the Arduino board files may have affected the way the EEPROM storage works; which is used to store the minimum and maximum level values. SC

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The Next M

Who do you think will be the next country to land a spacecraft on the moon? If you said any of the usual suspects – the USA, Russia, China or perhaps even India, the chances are you will be wrong. If all goes to plan, the next country to land their own spacecraft on the moon will be Israel – population just 8.5 million!

by Dr David Maddison

oon Landing

So far, there have been four countries that have landed spacecraft on the moon. The first country to land an unmanned spacecraft on the moon was the Soviet Union in 1959 with Luna 2, followed by a series of US and Soviet landings and then the first manned landing by the United States in 1969. India performed a controlled-crash impact in 2008 which was followed by China's landing of an unmanned spacecraft in 2013; the first soft landing on the moon since the Soviet Union's Luna 24 in 1976.

Even though Australia has never joined this august group, it once had a space program – which mostly started and stopped in 1967 with the launch of WRESAT (as described in Silicon Chip in October 2017 – www.siliconchip.com.au/article/10822). That demonstrated that small to medium-size countries could launch satellites.

Similarly, Israel with an area of just over 20,000km² and population much smaller than Australia (in fact, it has about the same population as New York City) has a space program – it has to date launched around 19 satellites (not counting nanosatellites).

It is the smallest country with an ability to launch its own satellites, one of only 11 countries to be able to do so. And so, the next country to land a spacecraft on the moon is expected to be Israel with a planned launch in late 2018 or early 2019 and an expected landing in mid-2019.

The initial plan was to launch in December 2018 and make a landing in February 2019 but delays unrelated to the Israeli lander have pushed it back by a few months (see http://siliconchip.com.au/link/aalj for more details on the delay).

Artist's impression of Israel's SpaceIL Sparrow craft on the surface of the moon.

Other competitors for the XPRIZE

In February 2011 a total of 32 teams had registered for the Google Lunar XPRIZE but by 31st December 2016, only five teams had fulfilled the XPRIZE requirement of having a verified launch contract and became contenders for the prize.

Apart from SpaceIL, these teams were Moon Express (USA; plans to launch 2019), Synergy Moon (International, negotiating to launch together with Team Indus), Hakuto (Japan, plans to launch 2020) and Team Indus (India, plans to launch 2019).

The Israeli lunar program is mostly privately funded and run by the non-profit organisation SpaceIL (www.spaceil.com/).

SpaceIL was initially formed to compete for the Google Lunar XPRIZE, a prize for landing a privately funded spacecraft on the moon, travelling 500 metres on the lunar surface and transmitting high-resolution video and images back to Earth.

Additional prizes were available for roving more than 5000 metres, capturing pictures of man-made objects on the moon or surviving a lunar night. The goal of the Lunar XPRIZE was similar to the Ansari XPRIZE, ie, to encourage private investment in low-cost space launch vehicles and spacecraft.

Since no team could meet the deadline for the XPRIZE of a launch attempt by 31st March 2018, the US$30 million pool of prize money went unclaimed.

But the XPRIZE Foundation announced on 5th April 2018 that the prize would be reinstated without the cash reward.

Regardless of the availability of the XPRIZE prize money, which was much less than the mission cost in any case, SpaceIL continues to prepare for the mission.

SpaceIL was founded by three young engineers: Yariv Bash, Kfir Damari and Yonatan Winetraub. They discussed the idea in a pub in Holon on a winter night in 2010 and decided to win the XPRIZE as a matter of national pride for Israel.

SpaceIL is mostly privately funded by various organisations and individuals including billionaire and former SpaceIL chairman Morris Kahn, who has donated US$28 million toward the US$88 million program cost. They also received a US$16.4 donation million from the Dr. Miriam & Sheldon G. Adelson Family Foundation.

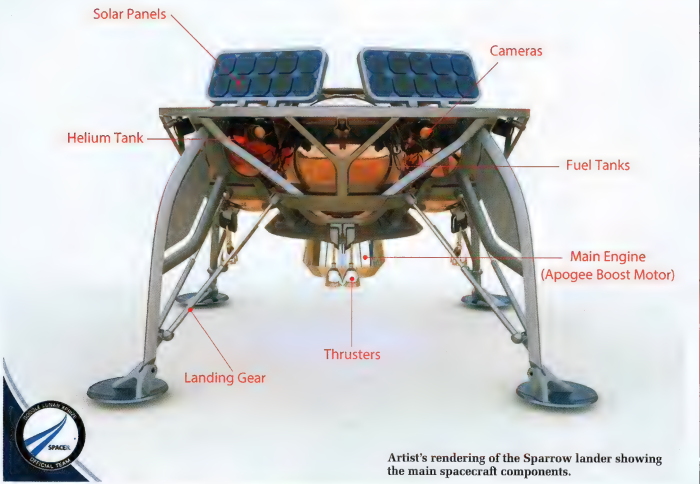
Other major donors include the Charles and Lynn Schusterman Family Foundation and the Parasol Foundation. There are also donors from academia, the aerospace industry, the telecommunications industry and educational institutions.

Objectives

While one of the original objectives for the SpaceIL mission was to win the XPRIZE, they also have other objectives. One of these is to inspire children to "think differently about science, engineering, technology and math" by creating an "Apollo effect".

Another objective is to acquire scientific data about the moon's magnetic field. A further objective is to develop new space technologies.

SpaceIL also intends to show the world that you don't



Artist's rendering of the Sparrow lander showing the main spacecraft components.

The planned trajectory of the lunar probe. This route uses the gravitational slingshot effect which takes longer but is much more energy efficient. See videos: *"SpaceIL Trajectory"* siliconchip.com.au/link/aalk and *"SpaceIL Landing Plan"* siliconchip.com.au/link/aall. Also see video *"Spacecraft's Orbit"* siliconchip.com.au/link/aalm .

have to be a superpower to land on the moon (an important lesson for Australia) and that it can be done on a small budget and with private funding.

For more information on their mission, see this video: *"SpaceIL Presents: The Mission"* **siliconchip.com.au/link/aalp**

The space vehicle

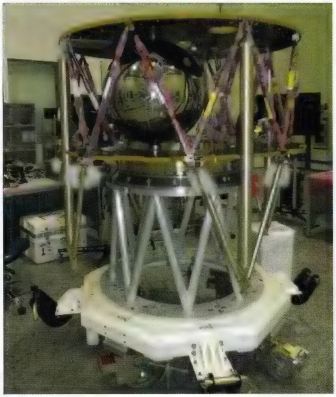
The lander that SpaceIL have developed is called Sparrow and is about is 2m in diameter, 1.5m tall and will weigh 585kg at launch; 400kg of that weight is propellant. Its scientific payload includes a magnetometer and cameras to take pictures on the moon. It has solar panels for power.

The reason for the large amount of fuel is that this spacecraft will only be delivered into Earth orbit by its launch rocket and it will then have to make its own way to the moon.

The ride

Sparrow will be launched on a SpaceX Falcon 9 rocket that will also be carrying other payloads including a communications satellite into geosynchronous orbit.

It will be the first time a "rideshare" is used to launch a spacecraft that is destined to travel beyond low Earth orbit.



(Above and right): views of the Sparrow lander during assembly. Visible are some solar panels at top, spherical fuel tanks in middle, gold thermal control material, reddish-brown thrusters, various wiring looms (many not yet connected or secured) and structural components. Barely visible is the bottom of the main engine nozzle at bottom centre. The fuel mass is the vast majority of the mass of the spacecraft. Note that the grey frame component with the diagonal members is a support structure and not part of the spacecraft.

Landing and stability tests of a prototype SpaceIL lander.

The "rideshare" service is facilitated by a company called Spaceflight (http://spaceflight.com/) which specialises in acquiring capacity on commercial launch vehicles and selling it on to customers "in the most expeditious and cost-effective manner possible".

[For details about the Falcon 9 see the article in last month's issue of SILICON CHIP (October 2018.)]

The trajectory and landing

The spacecraft will not fly directly to the moon like the Apollo spacecraft but will conduct a number of engine burns to place the lander in an increasingly eccentric orbit around the Earth, which will eventually be large enough to also encompass the moon. These engine burns are also designed to correct any orbital inaccuracies.

This is a much-more-energy-efficient scheme than the direct route, saving weight and fuel and greatly reducing the cost of the launch.

This type of manoeuvre is called gravity assist (or a gravitational slingshot) and was most famously used by the Mariner 10 and Voyager interplanetary probes. The downside of using this technique is that the SpaceIL mission journey to the moon will take about two and a half months rather than a few days.

As mentioned earlier, the SpaceIL lander will be one of several payloads on the Falcon 9 rocket. The lander will be released first, to be placed in orbit around the Earth in preparation for its trip to the moon, while other unrelated payloads will continue on into geostationary transfer orbit.

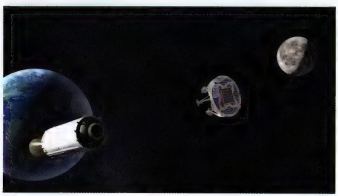
Once the Sparrow lander is in orbit around the moon, that orbit will be circularised at an altitude of 100km, at which point the spacecraft is travelling at 7000km/h.

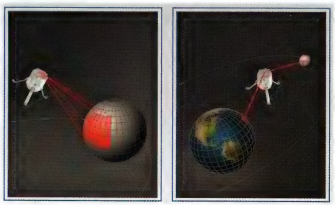
It will then initiate a deceleration burn, reducing its altitude to 15km. Then the landing sequence will commence.

The tallest mountain on the moon is 6.5km high so it is critical to get the landing location correct.

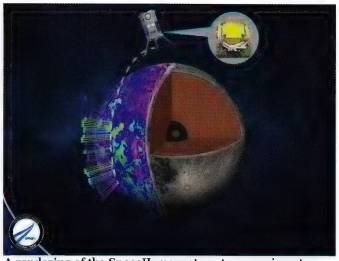
The rocket engines will be turned off 10 metres above the lunar surface and then the Sparrow will free fall to the ground.

The timing of the landing is critical and is designed to coincide with sunrise on the moon, as the low angle of the sunlight will increase the visibility of obstacles due to


Artist's rendering of the SpaceIL lander at the moment of separation from the Falcon 9 second stage, which will then take other unrelated payloads into to geostationary transfer orbit or geostationary orbit as part of a "rideshare".


Illustrations depicting the operation of the OpNav (left) and Earth Moon Sensor (right) camera-based navigation systems

Sparrow fuel tanks being integrated with the spacecraft chassis. There are four fuel tanks, two for oxidiser and two for propellant. The tanks are made of titanium, less than 1mm thick, and contain a system to minimise sloshing of the fuel which would destabilise the spacecraft. The system also separates liquid from gas to prevent entry of gas bubbles into the engine. The orange elements affixed to the tanks are heaters, part of the spacecraft's thermal control system, to keep the fuel at an appropriate temperature.



A rendering of the SpaceIL magnetometer experiment. Lunar magnetic fields are to be measured during landing, after landing and during the subsequent 500 metre "hop". The spacecraft portrayed in this graphic is an earlier prototype but the experiment is the same.
See siliconchip.com.au/link/aalq

the long shadows they will be casting. Bear in mind that a lunar day lasts 29.5 Earth days so this occurrence only occurs about monthly in Earth terms.

The lander has an artificial intelligence optical hazard detection system, rather than traditional radar, that will help it identify hazards such as large rocks or craters and avoid them during the landing process.

This optical landing system was developed by a biomedical scientist specialising in brain control processes.

Imagery from the descent will also be transmitted to ground controllers back on Earth. This is critical since, after landing, the Sparrow will take off again and travel 500 metres in a single "hop". It will need to avoid any nearby obstacles during the hop.

This hop is a fundamental requirement to win the XPRIZE. Sparrow will reignite its engine and rise 220 metres into the air, landing 500 metres from its original landing point.

Heating of the spacecraft by the Sun will also be a problem when it is on the moon. The fuel tanks will still contain some fuel set aside for the hop and if they reach 50°C, there is a chance they will explode.

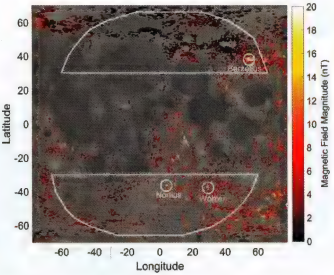
This temperature is estimated to be reached three days after landing, so the hop must be completed within that time. After the hop, there will be little or no fuel left in the tanks so there will be no risk of explosion.

The Sensonor STIM300 Inertial Measurement Unit used on the spacecraft.

Choosing a landing site

Naturally, a spacecraft doesn't just land anywhere, The landing site must be carefully selected in advance based on a number of constraints.

Firstly, the size of potential landing sites were selected as a circular area, 15km in diameter with suitable properties in terms of rock abundance, topographic variation, albedo



Map of potential lunar landing sites with the three strongest candidate sites circled. Colours indicate the strength of the magnetic field.
Image courtesy Y. Grossman, O. Aharonson and A. Novoselsky. **siliconchip.com.au/link/aaln**

(reflection of solar radiation), slopes and surface roughness.

Areas with rocks larger than 10cm diameter were avoided. Topographic variation was to be minimised within specified limits. Albedo is important because the lander uses a laser altimeter, so the lunar surface must have a suitable level of reflectance. Steep slopes are avoided to prevent the lander from tipping over and surface roughness should be minimal

Additional considerations were made for surface temperature and communications (ie, radio visibility between the lunar and Earth uplink and downlink sites).

After sites were selected according to the above criteria, they were then culled based upon SpaceIL's scientific objective of characterising the crustal magnetic field. So areas with particular magnetic field interest were chosen as candidate landing sites leaving three main options.

The magnetometer experiment

Unlike the Earth, the moon has only a very weak magnetic field and does not have a geodynamo of circulating molten iron such as gives rise to the magnetic field on Earth.

What magnetic field does exist on the moon arises mainly from the magnetisation of crustal rocks and this varies according to location. The history and origin of the lunar magnetic field is still unclear, hence the desire to acquire magnetic field data as part of the SpaceIL mission.

The experiment to obtain magnetic field data is known as the Lunar Magnetometer or LMAG. A magnetometer is a device to measure magnetic fields (it is also commonly found on smartphones).

In fact, we have an article on two magnetometer (eCompass) chips in this very issue, starting on page 72.

Lunar magnetic fields have been measured before; Apollo astronauts measured fields but only near their landing sites.

NASA's Lunar Prospector measured fields globally but only at relatively low resolution, as the readings were taken from orbit.

SpaceIL will build on these results by taking magnetic field readings from a range of heights as the spacecraft descends, when it lands and when it makes the 500-metre hop to its second location.

Navigation

The Sparrow lander has several elements to its navigation system. These are a star tracker, an Inertial Measurement Unit and unique software based systems called the Earth Moon Sensor and OpNav.

The star tracker is a camera which takes pictures of the stars and compares them with a database of (typically) 57 particular stars commonly used for spacecraft navigation in order to determine the orientation and attitude of the spacecraft.

Once it has identified several of those stars in its field of view, by comparing their positions to the information in its database, it can figure out its orientation.

The Sparrow will use a Berlin Space Technologies ST200 star tracker which is one of the smallest and lightest such devices available. It was originally designed for CubeSats and weighs just 40g. It draws just 650mW from a 3.7V - 5.0V supply

The Inertial Measurement Unit will be used at all phases of SpaceIL's flight, landing and its hop on the moon to measure the acceleration and rotation due to engine and thruster operation.

It can also be used as a navigation backup in the event of failure of the star tracker. It contains three MEMS (micro-electromechanical systems) gyros representing three axes, three accelerometers and three inclinometers.

The Earth Moon Sensor is a unique camera and software package which will take pictures of the Earth and moon and identify them according to their size and colour. It can then locate the centres of both bodies, enabling the spacecraft to determine its position with respect to both.

OpNav is a newly developed optical navigation system that takes pictures of the moon and transmits the images to Earth whereby the spacecraft position is determined by comparing the images with existing maps.

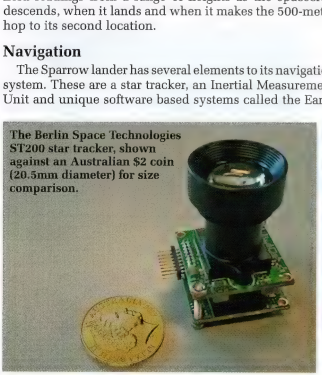
Communications

The transceiver used by the lander was developed by the US company Space Micro. It operates in the 2- 4GHz S-band. The receiver section operates at 2025MHz-2120MHz and the transmitter section at 2200MHz-2300MHz.

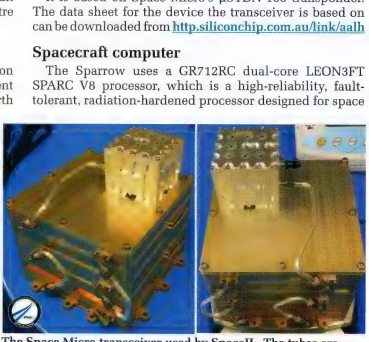
It is based on Space Micro's µSTDN-100 transponder. The data sheet for the device the transceiver is based on can be downloaded from http.siliconchip.com.au/link/aalh

Spacecraft computer

The Sparrow uses a GR712RC dual-core LEON3FT SPARC V8 processor, which is a high-reliability, fault-tolerant, radiation-hardened processor designed for space



The Berlin Space Technologies ST200 star tracker, shown against an Australian $2 coin (20.5mm diameter) for size comparison.



The Space Micro transceiver used by SpaceIL. The tubes are waveguides for the high frequency RF signals.

The mission computer (an early prototype board from September 2012).

applications. It is capable of clock speeds up to 100MHz and performance of 200MIPS and 200MFLOPS peak. The processor is fabricated by Tower Semiconductors Ltd. in Israel.

Comparison between the computing power in the Sparrow and the miniscule amount in the Apollo spacecraft, including those which transported men to the moon, are enlightening. (It's often claimed that today's mobile phones have significantly higher computing power than did the Apollo craft!).

Spacecraft cameras

If only to prove it was there(!), arguably one of the most important elements of the spacecraft are its cameras. The camera model chosen (Berlin Space Technologies ST200) has two video processors for redundancy in the event of a failure of one processor, has 8MP (greater than 4K) resolution, an autofocus lens, can work within the temperature range of -120°C to +120°C and weighs 130g.

The lens elements are made of borosilicate glass due to its low coefficient of thermal expansion.

Preserving the early lunar landing sites

The XPRIZE offered a US$4 million bonus for photographing other man-made objects left on the moon. This caused alarm amongst some, concerned that historic landing sites (especially the Apollo sites) would be ruined by such visitation.

The concern about preserving these sites led to The White House Office of Science and Technology Policy (OSTP) releasing a report on the matter, *"Protecting & Preserving Apollo Program Lunar Landing Sites & Artifacts"* (available via **siliconchip.com.au/link/aalo**).

Preservation of these sites will require international cooperation. SC

STOP PRESS: Elon Musk (SpaceX) announces first "lunar tourist"

Further to our feature last month – "Reusable Rockets" (**www.siliconchip.com.au/Article/11257**), Elon Musk told the world's press on September 17 that Japanese IT billionaire Yusaku Maezawa would be the first paying customer on SpaceX's first Big Falcon Rocket (BFR) around-the-moon project.

The commercial site-seeing expedition would take about a week to travel the 770,000km (480,000 mile) round trip to the moon. Maezawa stated that he wanted to take along a range of creative people – artists, writers, photographers, etc to record the event for posterity.

Musk also revealed the target launch as just five years away, during 2023. During that press event, he showed off new renderings of the launch system, along with a few photos of the work going on inside SpaceX's spaceship-building tent at the Port of Los Angeles.

These were the first new details about SpaceX's rocket construction since April, when SpaceX revealed they were building the carbon-fibre spacecraft using a 40-foot-long, 30-foot-wide cylindrical tool (12m x 9m).

SpaceX appear to be using a new technique for carbon-fibre construction. Whereas carbon-fibre technology usually has tapes woven into a fabric the soaked with a resin, experts believe the BFR is being built with unwoven tapes wrapped around a giant mandrel, then soaked with the epoxy resin. They maintain that this should result in a craft which has the highest stiffness and strength, without the kinking or wrinkling of woven tape.

With an estimated development cost of $US5 billion, the BFR appears to be in direct competition with NASA, currently building a giant, one-use launcher called Space Launch System. However, research, development and construction costs of this craft may be more than $US20 billion and about $US1 billion to launch.

Early reports suggest that once the SpaceX BFR spacecraft is operational, it may cost the company as little as tens of millions to refuel and launch – again and again. SC

The Christmas

It's an *unwritten law* in Australia that your house has a better Christmas lights display than your neighbours . . . And perish the thought that you have one the same as anyone elses!

Well, build this one and you'll have an awesome display, totally unlike anything else around, with the requisite flashing lights (in green, red and white, of course). You might even get some elves to give you a hand building it.

By Santa's Little Helper – Tim Blythman

See Page 101 for an exclusive PCB/kit offer!

Just one of the many possible trees that you can build by stacking these boards together. This one is 80cm tall, 64cm wide and uses 38 boards with 304 LEDs.

ree that Grows!

And just how does it grow? Surely it's not alive? Well, not quite – but it can grown from a single tree about 150mm high to a monster, as high as you want.

The reason for this is that it's made from stackable PCBs – you just build another board and plug it in! And each one is cheap and easy to build, so it won't take much effort to make a big tree display.

The concept is simple – but ingenious at the same time. Each PCB is shaped like a small tree with three branches and has eight LEDs which can be controlled in any manner that you wish, to create many different kinds of patterns.

Not big enough?

If you want more, another three PCBs can be connected to the end of each branch, then another three PCBs can be stacked on those branches and so on, to form a bigger and bigger tree.

When the PCBs are stacked, power and data are automatically fed through, so you need just one low-cost controller board no matter how big your tree is.

If you want a huge Christmas tree, you could use, say, 38 boards, as shown in opposite, to make a big "pinetree"-shaped arrangement the best part of a metre high, with a total of 304 flashing LEDs.

Wouldn't that look absolutely spectacular?

Want even bigger?

Hey, the only practical limit is how you are going to support a 20m high tree . . . and supplying enough power for the number of PCBs.

(Each one draws about 25ma, so a huge tree is going to need a few amps @ 5V. Now *there's* a practical use for that old computer power supply gathering dust in the cupboard!)

You could even collaborate with your friends, family and/or classmates, by each building a few boards and then bringing them all together to build a huge tree.

It's also an excellent project for beginners since it's easy, fun and safe, using low voltage – and you can learn about electronics at the same time.

How it works

Each board contains eight LEDs with current-limiting resistors, one IC, one capacitor and four optional headers (to connect further boards).

The IC is the key to this design. It is a 74HC595 eight-bit shift register with output latches. That's a pretty complicated description but the way it works is relatively simple. Let's discuss the output latches first.

A latch is a circuit with one digital input, one digital output and a latching signal line. When you send the latch signal, the output state is set to the same as the input state (either low or high).

It stays that way until you send another latch signal. So if a LED is connected to the output of a latch, you can set it to be either on or off, and it will remain that way until you decide to change it.

If we connect all the latch signal lines together, we create a single wire which can be used to update the state of all the LEDs simultaneously.

Therefore we can update the latch inputs several times per second and then trigger the latch signal lines, setting the state of each particular LED on or off as desired, and they will stay in that state until another update comes along. This lets us create the LED patterns on the tree.

Shift registers

So how then do we control the state of each latch input to select the LED on/off states?

We *could* use a parallel scheme with one wire per latch but then in the case of the large tree opposite, with 304 LEDs, we would need 304 wires (plus a few for the latch signal, ground, power etc).

That would be far too unwieldy.

This is where the shift registers come to the rescue. In addition to eight separate latches to drive eight LEDs, each 74HC595 logic IC also contains an eight-bit shift register.

You can imagine this like a clear plastic tube which can hold eight coloured balls.

Say the balls are black or white to represent zero and one bits. This is shown in Fig.1.

If you push a new ball (of either colour) into one end of the tube, they all move along one position, and the last one falls out the end. If you feed eight new balls into one end of the tube, one at a time, once you have finished, all the old balls will have fallen out and the resulting black/white pattern will be determined by the order in which you inserted the balls.

Now if we place several of these tubes end-to-end, we can keep feeding in balls into the first tube and eventually, we will have replaced all of the balls in all of the tubes.

This is essentially how our chain of shift registers works. We feed bits into the first register in the chain, one at a time and they are "shifted" through the first register. Each time, the bits stored in the register move along to the adjacent bit position and the last one, which would be lost, is presented at one of the IC outputs.

This can then be fed into the next register in line.

So we only need two "data" wires – a

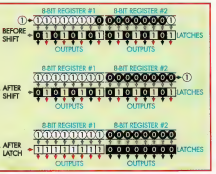


Fig.1: this shows how a shift register with output latches works. In this example, two 8-bit shift registers are chained to effectively form a single 16-bit shift register. When a new "1" bit is shifted in from the left (at the first register's input), all the bits shuffle to the right by one step. Then, when the latch signal is applied, the new values within the shift registers are copied to the latches and thus the output states change.

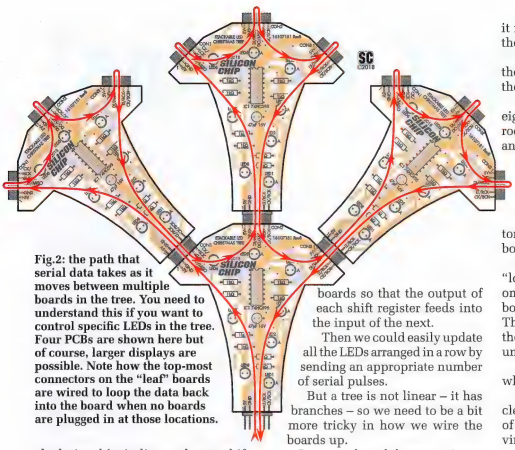


Fig.2: the path that serial data takes as it moves between multiple boards in the tree. You need to understand this if you want to control specific LEDs in the tree. Four PCBs are shown here but of course, larger displays are possible. Note how the top-most connectors on the "leaf" boards are wired to loop the data back into the board when no boards are plugged in at those locations.

clock signal (to indicate when to shift the bits) and a data signal (to indicate the value of the new bit to feed in) and we can update any number of registers.

We just need to send exactly the right number of clock pulses. These shift registers feed into the latch inputs mentioned earlier. So after shifting all the required bits into the registers, we send the latch signal and all the LED states are updated with the values that we just transferred serially (ie, one at a time).

Connecting and arranging multiple boards

If we were trying to create a LED bar graph – ie, where each set of eight LEDs is simply stacked next to the last – then we could simply wire up the boards so that the output of each shift register feeds into the input of the next.

Then we could easily update all the LEDs arranged in a row by sending an appropriate number of serial pulses.

But a tree is not linear – it has branches – so we need to be a bit more tricky in how we wire the boards up.

Our tree board has one input connector, to update the eight LEDs on the board itself, plus three outputs, going to each of the three possible branches. And you might not fit all three branches. In fact, for the "leaf" boards at the outside edge of the tree, none of the branches would be fitted.

So how do we make the shift register chain work? We use something which is known in mathematics as a "depthfirst" algorithm. Imagine you have a tree made of four boards, as shown in Fig.2.

There is one "root" board, plus three "leaf" boards attached to each of its branches.

Data is first shifted into the eight-bit register on the root board. Its output is then fed to the first leaf board, where it is shifted into the eight-bit register there.

The output of this first leaf board is then fed back into the root board, and then into the second leaf board.

It is then shifted through the third eight-bit register, then back into the root board, to be passed onto the fourth and final eight-bit shift register. It then returns to the root board and goes out the bottom.

That data is ignored since it will be the old data, which is no longer needed. But it must go out the bottom in case there is another layer of boards underneath.

You will note that the data is shown "looping back" around the branches on each leaf board, where another board could be connected but is not. This is arranged simply by bridging the input and output pads on those unused connectors.

That is how each board "knows" where to route the signal.

You would agree that this is a pretty clever way to get data to all the parts of the tree with minimal effort and virtually no wiring.

And where does the data come from in the first place?

You could use a variety of different sources such as an Arduino or Raspberry Pi, but later on in this issue, we will present a very simple and cheap control module.

This can be used independently, with pre-programmed patterns, or connected to a computer via its USB port and used in conjunction with computer software to drive the LEDs on the tree.

We will also provide instructions on how to control the Tree using an Arduino later in this article.

Circuit details

The circuit of each root/branch/leaf board is identical and is shown in Fig.3. IC1 is the 74HC595 shift register and its latch output pins are labelled Q0 through Q7. Each of these is connected directly to the anode of one of LEDs1-8, so if the latch output is high, the LED lights up.

The LED cathodes are connected to ground via 1kΩ current-limiting resistors, giving a typical current, with a 5V supply, of 3mA (5V – 2V)÷1kΩ. This is suitable for high-brightness LEDs but you may want to reduce the resistor values (to say 220Ω) if using standard LEDs, to give them enough current to

Parts List – LED Christmas Tree
(for each board – build as many as you want!)

1 double-sided PCB, code 16107181, 100mm x 93mm
1 74HC595 shift register,16-pin DIL package (IC1) [Jaycar ZC4895, Altronics Z8924]
8 high-brightness 5mm LEDs (LED1-LED8; a mix of green, red and white recommended)
8 1kΩ 1/4W or 1/2W resistors
1 47µF 16V electrolytic capacitor
1 100mm length of 0.7mm diameter tinned copper wire (to join PCBs) ***or***
1 6-way pin header ***and***
3 6-way female header sockets ***and***
3 2-way pin headers

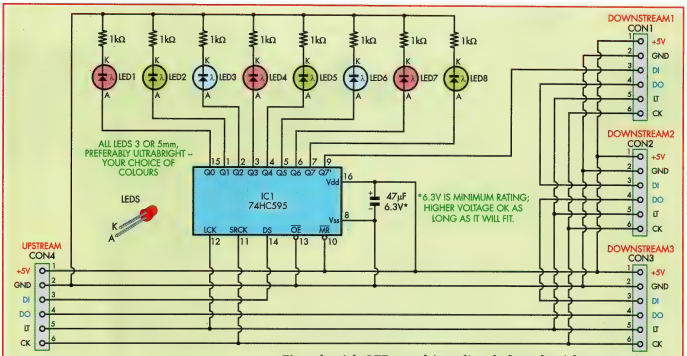


Fig.3: the eight LEDs are driven directly from the eight output pins of shift register IC1, with 1kΩ current limiting resistors setting the current through each to around 3mA.

LED TREE DISPLAY BOARD

produce reasonable brightness.

But this would increase the overall current demand, which could be a problem if you're using many boards to make a big tree. So we recommend that you stick with high brightness LEDs.

A 47µF electrolytic bypass capacitor is connected across the supply pins of IC1.

This is important since there are many connectors and tracks between the root and the leaves of a big tree and that could cause transient voltage drops due to wiring and contact resistance. A bypass capacitor helps to smooth out the local supply voltage

The rest of the circuit is just wiring between IC1 and the four connectors; CON4 is at the bottom of the node and for the root board, is connected to the controller. This is where the data comes in.

CON1-CON3 are on each of the three branches. On all four connectors, pin 1 is the +5V supply and pin 2 is GND (0V). These are all connected in parallel, to feed power to all the branches. Pin 5 is the latch signal while pin 6 is the serial clock signal; these are all routed in parallel to all the branch connectors too, as well as to pins 12 and 11 of IC1 respectively.

When pin 12 transitions from a low (~0V) to high (~5V) voltage, that causes the eight latches inside IC1 to be updated with the new values from the shift register. And since pin 12 of all the 74HC595 ICs in the tree are connected together, they all update simultaneously.

All the serial clock pins are also joined and this causes all the shift registers to shift simultaneously, forming our serial data chain. The remaining two pins are for the serial data. Pin 3 on CON4 is the serial data input and pin 4 is the serial data output.

Pin 3 is routed to pin 14 on IC1, the shift register serial data input. The serial output from IC1, at pin 9, goes to pin 3 of CON1, then the data from CON1 (pin 4) is routed to CON2 (pin 3), then from CON2 to CON3, and from CON3 back to CON4 – refer to Fig.2 to see how the data travels in the tree.

As mentioned earlier, if there is no board connected to either CON1, CON2 or CON3 then you merely bridge pins 3 and 4 (with a short piece of wire or a blob of solder) to route the signal on to the next branch, or back up to the "parent" node, in the case where CON3's pins are bridged. This is shown in the photo of the single board overleaf.

There is just one more pin on IC1 to consider and that is pin 13, the $\overline{G}$ input, which can be used to disable all the outputs. We aren't using this and so that pin is tied to ground. The outputs are therefore always enabled.

Controlling it

Fortunately, controlling a shift register is quite easy, although you need to be mindful of the order in which bits need to be presented.

The first thing to keep in mind is that the first bit shifted into the tree sets the state of the last LED and the last bit shifted in sets the state of the first LED.

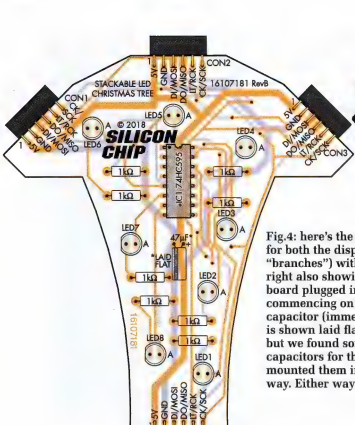
The other thing to keep in mind is that since the data "snakes" its way through the tree, as shown in Fig.2, if you need to know which LED is which, you will have to trace out this data path to figure it out. But many patterns can be generated where it doesn't matter exactly which LED is which.

For example, if you just want to make the LEDs twinkle, you can essentially feed random data into the tree and update the latches periodically.

Or you can take advantage of the "snaking" pattern by slowly shifting one bit at a time and updating the latch, to make the pattern "march" through the tree. These are both modes that our controller can provide.

Pretty much any device that can drive three digital outputs can be used to control the tree.

You can use a 3.3V-powered device,



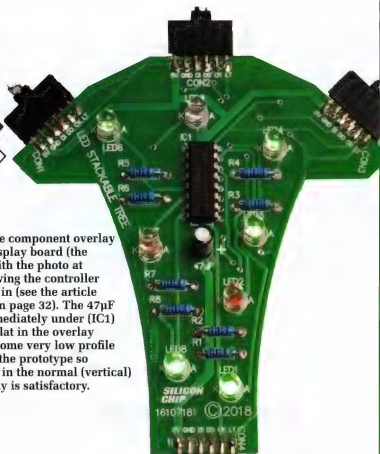


Fig.4: here's the component overlay for both the display board (the "branches") with the photo at right also showing the controller board plugged in (see the article commencing on page 32). The 47µF capacitor (immediately under IC1) is shown laid flat in the overlay but we found some very low profile capacitors for the prototype so mounted them in the normal (vertical) way. Either way is satisfactory.

such as a Micromite or Raspberry Pi, but in this case, you should use a power supply voltage for the tree in the range of about 3.3-4.5V, which will result in slightly dimmer LEDs (but probably still bright enough, as long as they are high-brightness types).

If you power the tree from 5V but use a 3.3V signal source, it may work but it's possible that it won't since with a 5V supply, the 74HC595 is only guaranteed to detect a voltage above about 3.5V as a logic high level.

Having said that, we're yet to come across a 74HC595 which will not work with a 3.3V signal. Make sure you don't feed the output from pin 4 of your tree root back to a 3.3V chip though. Generally, there is no reason to do this and it could damage the IC.

If you do run into problems driving the tree from a 3.3V source, you could use a logic level translator to boost the output of your 3.3V device up to 5V. Luckily, since the control scheme is serial, you only need to translate three signals.

Connection options

Ideally, once you have built all the boards and decided on the shape of your tree, you should permanently connect the boards using short lengths of stiff wire (eg, tinned copper wire).

This makes the whole tree quite rigid and able to support its own weight, unless you are creating a real monster. For example, you could hang the tree from a wire soldered to the top. This is also the cheapest construction method.

If you want to experiment and play around, you can use pin headers and sockets, as shown in our photos. That makes it really easy to experiment with the boards but you need to lay them on a flat surface for this to work.

Otherwise, if you try to stand the tree up or hang it, it will probably flop around and may pull itself apart under gravity. The sockets don't have that much retention force.

So it's up to you; if you want maximum flexibility, use a six-way pin header for CON4 and female header sockets for CON1-CON3. Two-way pin headers with a solder blob across the base can be used to "terminate" the sockets with nothing plugged into them, as shown in our photos.

PCB assembly

There are very few components needed to build a single board and it doesn't take long to build it. Use the PCB overlay diagram, Fig.5, as a guide. The board measures 93 x 100mm and is coded 16107181.

Start by fitting the resistors. Whether you use the 1kΩ specified for high-brightness LEDs [brown-black-black-brown-brown (1% tolerance); or brown-black-red-gold (5% tolerance) or the 220Ω (red-red-black-black-brown or red-red-brown-gold) for standard LEDs, the values are all the same.

So all you need to do is bend their leads so they fit through the provided holes (a lead forming tool is helpful), push them down onto the board, solder the leads to the pads on the underside

and trim off the excess lead length.

While it doesn't matter which way around they go, it looks neater if the colour coding rings are all orientated the same way. It's also a good idea to make sure they are fitted straight, again, to make it look neat.

This is easier if you solder one lead first, then check that they are lined up correctly, then solder the other lead.

Be sure to check all the solder joints when they are finished, to make sure they are shiny and contact both the lead and PCB pad properly.

We recommend that you solder IC1 directly in place, although you could fit a socket to the board and then plug the chip in if you prefer to do so. Push the chip right down onto the board making sure that its pin 1 notch is facing towards the left, as shown in Fig.5.

Also make sure the IC leads go through the holes and do not fold up underneath it.

DIP ICs are designed to be installed by a machine, so their leads may be splayed outwards slightly, making it a bit more difficult to insert them by hand.

If you're having trouble, try carefully bending the leads inwards slightly. You can use pliers but a purpose-made IC lead bending tool is even better.

Install the LEDs next. You can use whatever colours you like; you could make all the LEDs on one board the same colour but different to another board, or you could mix different colours on the one board.

Regardless, make sure that each one is orientated correctly before soldering it in place. The longer (anode) lead must go through the hole marked "A" on the PCB. We elected to push our LEDs all the way down onto the PCB before soldering and we recommend that you do the same.

Next, fit the electrolytic capacitor. It is also polarised and must be orientated correctly.

In many cases the electro will be too tall to solder in the conventional way – it can be laid over on the board and the pins soldered down 90°. The longer positive lead must be soldered to the pad marked "+" on the PCB (the stripe on the can indicates the negative lead).

Header

As mentioned earlier, the best way to join the boards to form a big tree is with short lengths of 0.7mm diameter tinned copper wire. You save the cost of headers that way.

You could use right-angle headers but we have used straight headers and surface-mounted them sideways, for a couple of reasons.

Firstly, right-angle female headers are very hard to get. And secondly, this makes it easier for the whole assembly to sit flat.

Even if you are using fixed wires for most of the connections, we recommend that you use a female socket for CON4 on the bottom-most (root) board, to make it easier to connect up your control system.

To solder straight pin headers like this, it's easiest to hold the six-way pin header in a female socket strip. That helps to keep the pins lined up and also provides some insulation for your fingers from the heat of the iron.

Solder one pin first and ensure the header strip in flat, level and flush with the PCB. If that is the case, solder the rest of the pins. If not, apply the iron to the soldered pin and adjust it before soldering the remaining pins.

Testing

It's a good idea to test each PCB by itself before joining them all together, especially since a problem with one PCB might affect the operation of other PCBs, making it hard to work out which one actually has the problem.

The easiest way to do this is to use the control system you plan to use for the whole tree but connect it up to one board at a time.

If you haven't prepared that yet, you can use an Arduino programmed with the software described below. Once you are happy that the boards are working, you can start assembling them into a larger tree.

One from many

If you have built all your boards with headers, you just need to plug them all together. Note that as the tree gets larger, there are some sockets that you can't use, as the boards would overlap. You need to choose which one of the two conflicting boards you want to fit.

Look at the opening page for an idea of how this can be done.

Once you have finished, any boards which have nothing plugged into CON1, CON2 or CON3 will need a jumper connecting pins 3 and 4. If you have not used sockets, bend a component lead off-cut into a "U" shape, push it into the pin 3 and 4 pads for the relevant connector, solder it at both ends, then trim the excess lead.

If using sockets, you can use a small

What kind of power supply do you need?

These boards are designed to run off 5V, although you could get away with running them from a slightly lower voltage.

But since 5V supplies are very common, you might as well stick with that.

If you build the boards as specified, they will draw a maximum of about 25-30mA. That means you can run up to 16 boards (500mA ÷ 30mA) off a single USB port.

Having said that, most USB ports will deliver well over the 500mA minimum and most USB chargers are capable of at least 1A – and usually more than 2A.

So you could easily run a big tree off most USB supplies – including (but not limited to) the large 38-board version shown earlier.

But there's not much to stop you from making a much bigger tree. You could combine more than 100 boards to make a huge one, well over a metre tall. You may need to attach the boards to a rigid backing for support but it should work.

Such a tree would draw several amps at 5V.

You can, of course, buy plugpacks and "brick" type supplies that can deliver that much current but why not re-purpose an old PC power supply?

They will usually deliver at least 5A from their 5V rail and in some cases, much more.

A pinout of the 20-pin AT or 28-pin ATX connector will let you identify which wires are 5V (usually red) and which are 0V (usually black).

You can then cut off the unnecessary connector, join several red wires together and several black wires together, to give you your +5V and 0V outputs, and then wire a toggle switch between the green wire and the 0V output.

Toggling that switch to the on position should then cause the power supply to start up.

Note that if your power supply has a brown wire (+3.3VSENSE, not present in all cases but if it is, usually on pin 13), then you will need to join it to one of the orange wires (+3.3V) to get the power supply to stay on.

Controlling the Christmas Tree with an Arduino

We have uploaded a simple test sketch to our website to test each board you build, by cycling through the LEDs in order.

It will work with just about any Arduino; we tested it with a Uno but you can use a clone, or a Leonardo or Mega.

If you haven't used an Arduino board before, you'll also need to install the Arduino Integrated Development Environment (IDE), which allows you to write programs (called "sketches") and upload them to the Arduino board.

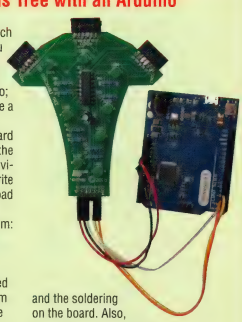
This can be downloaded for free from: **www.arduino.cc/en/Main/Software**

Once you have installed this software and opened our sketch ("Stackable_LED_Tree.ino"), you will then need to make the following connections from the Arduino to your tree root using five male-female jumper leads, as follows:

Arduino Board	Tree
5V	5V (pin 1)
GND	GND (pin 2)
D2	DI/MOSI (pin 3)
D3	CK/SCK (pin 6)
D4	LT/RCK (pin 5)

Next, select your board type and port from the Tools menu and upload the sketch to the board using the Upload button. You should then see the LEDs turn on one at a time, starting with LED1 and progressing to LED8.

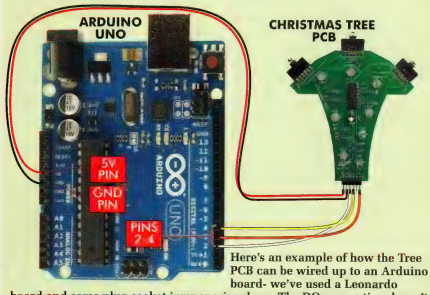
If more than one LED turns on, or any LED does not light, something is wrong with your board. Check your wiring and the soldering on the board. Also, check that the orientation of your LEDs is correct.



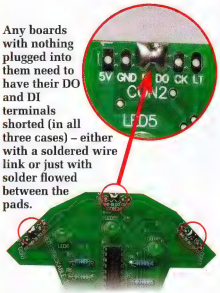
The sketch is designed to work with one board at a time but if other boards are connected, their LEDs should light up too.

You might notice that the LEDs on the other boards are delayed by comparison with the previous board. This is because the data from each board gets pushed onto the next board each one cycle later.

We have also written another sketch which provides a random twinkle effect, ideal for simulating a Christmas tree. It's called "Stackable_LED_Tree_Twinkle.ino" We've inserted plenty of comments in both programs to help you understand and customise them.



Here's an example of how the Tree PCB can be wired up to an Arduino board- we've used a Leonardo board and some plug-socket jumper wires here. The DO connection doesn't need to be connected, and is not used by any of the sample sketches.



Any boards with nothing plugged into them need to have their DO and DI terminals shorted (in all three cases) – either with a soldered wire link or just with solder flowed between the pads.

piece of tinned copper wire or component lead off-cut bent into a "U" shape, as long as it is thick enough to stay firmly in the socket.

Or you can short out a two-pin header with a blob of solder (see photo above) and plug this into the middle of the socket.

We even created small pluggable jumpers by taking a two way piece of male header, and bridging the two sides with a ball of solder. This is handy if you want to experiment with your tree layout.

On the other hand, if you have very small kids around, it might be a good idea to use the option of permanently soldering the jumpers in place, as you don't want them to get loose and be swallowed.

By the way, if you want to be really creative, you could make several smaller trees and join them together using lengths of 6-way ribbon cable; there's no reason why the boards have to be in direct contact with each other, as long as CON4 on one board is wired to CON1, CON2 or CON3 on another board without transposing the connections.

Depending on whether you want to connect your tree to an Arduino board or our dedicated controller, see the instructions at left or the following article.

We hope the Stackable LED Christmas Tree brightens up your Christmas and helps someone learn a bit about electronics!

And by next Christmas you'll be wanting to make up a whole lot more add-on boards for a monster tree!

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USB Digital and SPI Interface Board

We originally designed this simple, low-cost interface to control the Christmas Light Tree elsewhere in this issue. But then we realised that with a minor tweak here, a slight adjustment there, we would have a general-purpose controller which could handle up to eight digital lines from your PC, including an SPI serial interface. So here it is: use it for the LED Christmas Light Tree or anything else that comes to mind!

by Tim Blythman

This small board uses a low-cost PIC16F1455 microcontroller, which incorporates a USB interface, to drive up to seven digital outputs and one input, including three used for SPI (serial peripheral interface) communications.

This means that you can use it to control some external circuitry easily from your PC.

The LED Christmas Tree earlier in this issue has an SPI-compatible interface and so it can be controlled using this board but there are many other ICs which also use an SPI bus.

As a bonus, if the Interface Board is powered up but not connected to a computer (say, it's connected to a USB phone charger) it will output random patterns to allow the LED Christmas Tree to be used without a computer.

So if you want to develop a project around one of those ICs, this board would be a really easy way to experiment with such chips and test them out.

It can even be used to drive colour TFT LCD screens as many of these are based around an SPI interface, with the addition of a few digital control pins; this board can also drive those pins, using its four extra digital outputs.

You could also drive a standard alphanumeric LCD using this module. They typically require around 7 digital control pins; four for data and three for clocking/control.

Luckily, that's exactly what this board can provide. You can even use it to communicate over an I^2C interface.

It's based on a PIC

The PIC16F1455 used in this project is one of the smallest (and cheapest) PICs with a USB interface and impressively, it only needs three other components to work.

You don't even need to solder a USB socket onto the PCB (although there is space to do so), as we've made the end of the PCB into a plug that will fit into a standard USB-A socket.

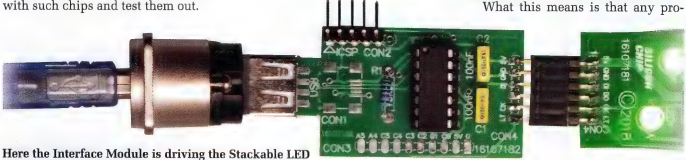
It isn't completely compliant with the USB specifications, but it's a technique that is quite widely used and it works fine.

Just keep in mind that the copper tracks can wear out if you're plugging and unplugging it a lot. In that case, a proper USB connector would be the way to go.

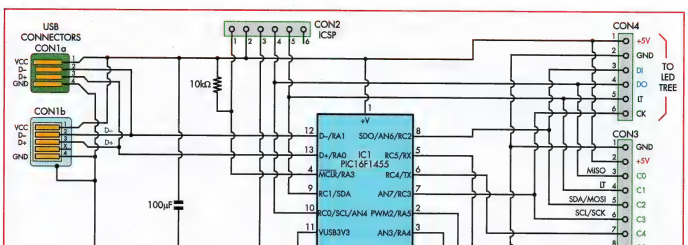
You might remember that the PIC16F1455 was used as the basis for the popular Microbridge PIC Programmer and USB Serial Converter, from the May 2017 issue (siliconchip.com.au/Article/10648).

The software we are using here is similar, in that it presents itself to the host computer as a serial port, but instead of producing a serial UART stream (compatible with RS-232), it generates an SPI stream instead.

What this means is that any pro-



Here the Interface Module is driving the Stackable LED Christmas Tree, using CON4 to make a direct connection.



LED TREE CONTROL BOARD

Fig.1: the circuit diagram for the Interface Board. IC1 is programmed to provide a USB interface via CON1, which can be either an SMD USB socket or tracks on the PCB which fit into a USB port. All of the PIC's free pins are wired to CON3 and CON4, to provide seven programmable digital outputs as well as an SPI or I²C serial bus, to communicate with external circuitry.

gram that can interface with a serial port on your computer can be used to control most SPI devices, including our Stackable LED Christmas Tree. We've provided a sample program in the Python language to use with our Christmas Tree but you can also use a terminal program such as the Arduino Serial Monitor to test out the commands and manually send SPI data.

Two control modes

The way the Digital Interface Board works is as follows. If it is configured with a board rate of 9600, then the interface works in hexadecimal SPI mode. If the baud rate is set to 19,200, then it works in binary SPI mode. A baud rate of 38,400 selects I²C mode (the data rate is 400kHz).

Note that these baud rates do not affect how fast the data is clocked out; they are just a convenient way of signalling to the Digital Interface Board which mode you want to use.

Hexadecimal SPI mode

Three of the seven digital output pins on the board can be used as an SPI serial bus. They are labelled SCK (the serial clock), MOSI ([data] master out, slave in) and MISO ([data] master in, slave out).

In hexadecimal SPI mode, the unit accepts the hex digits 0-9 and A-F (and their lowercase equivalents) over the USB serial interface.

The letters T-Z and t-z are also accepted, as described below. Any hex digit received will cause four bits of SPI data to be transmitted on the MOSI and SCK pins, with the most significant bit being sent first.

Any data that is received on the MISO pin (pin 10, RC0) is read back simultaneously with data being transmitted on MOSI. In this case, a hex digit is echoed back to the serial monitor.

The characters T-Z and t-z can be used to set the state of the pins directly, with the uppercase character setting the pin to high and the lowercase character setting the pin low, as shown in Table1 below.

This feature is used with the Christmas Tree to latch the data when required. Any other characters received over the USB interface are ignored.

For example, using the hexadecimal mode, we can turn off all the LEDs on a single board of the LED Christmas Tree by sending the string "v00V". This brings pin 9 low, then sends eight bits of zeros over the SPI bus, then brings pin 9 high, transferring the shifted data into the device's output latches.

Similarly, sending the string "vFFV" will turn all the LEDs on.

Because other characters are ignored, line endings don't matter and practically any terminal program can be used to send this data.

Note that there are only seven pins listed in Table1 because the eighth pin, pin 10, is only used as an input and only in SPI mode.

Control characters	IC1 pin pin	CON3 pin	CON4 pin
t/T	3 (RA4)	9	-
u/U	2 (RA5)	10	-
(input only)	10 (RC0, MISO/DO)	3	4
v/V	9 (RC1, LT)	4	5
w/W	8 (RC2, MOSI/DI/SDA)	5	3
x/X	7 (RC3, SCK/CK/SCL)	6	6
y/Y	6 (RC4)	7	-
z/Z	5 (RC5)	8	-

Table1: pin connections and control characters

Binary SPI mode

In binary SPI mode, we take advantage of the fact that USB data is sent in packets. Each time the Board receives a packet from the host, it sets LT low, clocks out the data using SCK and MOSI and then sets LT high again. It also reports serial data received on the MISO pin back to the host in binary format.

Parts list – USB/SPI Interface Board

1 double-sided PCB coded 16107182, 55mm x 28mm
1 PIC16F1455-I/P microcontroller programmed with 1610718A.HEX (IC1)
1 16-pin DIL IC socket (optional, for IC1)
1 mini USB type B SMD socket (CON1b; optional)
1 5-way right-angle (or straight) pin header (CON2, ICSP; optional)
1 10-way pin header or socket (CON3)
1 6-way female header socket (CON4)
2 100nF MKT capacitors
1 10kΩ 1% or 5% resistor, 1/4W or 1/2W

While this mode provides faster communications, it can only be used with a host terminal program that sends multiple bytes together, so that the data is received by the unit as a single packet.

This is possible with the Arduino Serial Monitor, provided that line endings are turned off, as these will otherwise appear as binary data to the unit.

If you are driving a Christmas Tree board in binary mode and see LED2 and LED4 on when you are not expecting them to be on, that indicates that you may have line endings still turned on, as this combination corresponds to the character that is used to terminate a line (line feed [LF], binary 00001010, ASCII code 10).

While trickier to use manually, this mode is more convenient for writing software which delivers data to the serial port directly.

Hexadecimal I²C mode

To make this board even more flexible, we have also added an I²C mode. In this mode, RC2 is used as SDA while RC3 is used as SCL.

To use it, you write one or more bytes to the serial port in hex format (ie, pairs of characters 0-9 or A-F), followed by a newline. When the newline character is received, the previous bytes are transmitted over the I²C bus.

Alternatively, you can prefix the bytes with "S" to start communication and follow with "P" to finish.

The first byte contains the 7-bit device address plus one bit to indicate read or write mode. The board scans this byte to determine whether you are doing a read or write and acts accordingly.

Each byte read is followed with a "K" to indicate if an ACK signal was received or an "N" if it did not receive the ACK. In read mode, after the initial address byte, you simply send "FF" for each byte you wish to read back. The response will then be read back and displayed along with the ACK/NACK indicators mentioned earlier..

The Board also supports 10-bit addressing mode. In this mode, the top five bits of the address byte are 11110, and a second address byte follows. It will detect this and act accordingly.

The clock rate for I²C mode is always 400kHz. Note that there are no I²C bus pullup resistors on the board. If your slave lacks pullups you will need to fit some yourself.

Check the I²C specifications to determine the correct pull-up resistors to use for your circuit.

Circuit description

The circuit of the Digital Interface board is shown in Fig.1. A 10kΩ pull-up resistor from pin 4 ($\overline{MCLR}$) of IC1 to VCC enables the power-on reset feature and allows for normal operation of the chip after power is applied.

One 100nF capacitor between VDD (pin 1) and VSS (pin 14) provides overall supply bypassing while another capacitor from pin 11 (VUSB3V3) to ground filters the internally generated USB 3.3V supply.

The proper USB socket and PCB track socket are wired in parallel, with the D- and D+ signal lines going to pins 12 and 13 of IC1 respectively. The software sets these pins to operates as USB signal lines rather than general purpose I/O pins.

An optional six-pin header in-circuit serial programming (ICSP) is provided (CON2), to allow IC1 to be programmed in situ. If you're using a pre-programmed chip, you can leave CON2 off the board.

Finally, CON3 and CON4 break out the digital I/O pins. 10-pin header CON3 provides connections to GND (0V) and the USB 5V rail, as well as the eight I/Os that the unit can control (RC0-RC5 and RA4-RA5).

By comparison, 6-pin header CON4 only includes the four signal connections which are required for SPI or I²C communications, along with the GND and 5V connections.

This suits the LED Christmas Tree board, which can be plugged straight into this header. But it could also be used in any other situation where you just need to communicate with an SPI or I²C device.

As mentioned earlier, the RC0 pin on IC1 is used as an input only, in SPI mode, while the other seven pins are digital outputs. Outputs RC2 and RC3 can be used for either SPI or I²C serial communications, or as general purpose I/Os.

Construction

Use the PCB overlay diagram, Fig.2, as a guide during constructions. The USB Digital and SPI Interface Board is built on a PCB coded 16107182, which measures 55 x 28mm.

If you intend to install the optional USB socket, we recommend doing that first, before any other components are in the way. To do this, the USB projection on the PCB needs to be snapped or cut off; otherwise, it would foul the ca ble.

Firstly, score along the line of "mouse bites" to help the PCB break cleanly. This will also help to sever the PCB traces so that they don't tear when the board comes apart. Flex the board at the score line and it should snap. Clean up any rough edges with a file.

The USB socket is the only SMD component used. We recommend that you put a thin smear of flux paste on the pads before soldering.

The socket has plastic pegs on its underside to locate it on the PCB. Once positioned, ensure it is flat and solder the large mechanical tabs on the sides to lock it in place.

Here's an enlargement of the USB "plug" section of the PCB, which is removed if a micro USB socket is used (as shown opposite). Score along the "mouse bite" holes before snapping this section off and clean the edge with a file.

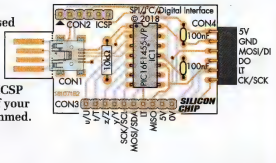


Fig.2: it doesn't get much easier than this. IC1 is the only polarised component; make sure to fit it with the orientation shown here. You can use a socket if you don't want to solder the chip directly to the board. The ICSP header, CON2, is not required if your micro has already been programmed.

With a clean, fine tip loaded with a bit of extra solder, carefully apply the iron to the pins and pads. The flux should draw the solder up and onto the pins. Solder all the pins and inspect them to ensure there are no bridges between adjacent pads. If there are bridges, remove them with some additional flux paste and a piece of desoldering braid (solder wick).

Required components

There is just one resistor on the board, so solder that in place next. Follow with the two identical capacitors. None of these components are polarised.

If you are using an IC socket for IC1 (which is handy if you plan to use an external programmer), fit it next, ensuring the notch is facing towards the top of the board, as shown in Fig.2.

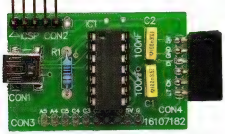
If you will be plugging CON4 into a Stackable LED Christmas Tree board, you should ensure that it will line up nicely before soldering it.

We suggest that you solder one pin in place and then check the alignment is correct before soldering the rest.

You don't need to fit CON2 if you have purchased a pre-programmed PIC. But note that even if you will be using it to program IC1, you can plug it in and hold it in place while programming the chip, then remove it.

If you are programming IC1 using an external programmer, do so now (see panel for instructions), then plug the programmed chip into the socket.

Or, if you're not using a socket, solder it to the board now but make sure it is orientated correctly first.



The simplest connection method is to plug the PCB straight into a USB port, but if you fit a socket as shown here, the result is a bit more robust. It also makes the board slightly more compact.

Using it

To use the Digital Interface Board to drive the Stackable LED Christmas Tree, plug the root board of the tree into the six-way socket on the Interface Board, with both boards facing up so that the pin names match.

Plug the Interface Board into a USB port on your computer and open a terminal program such as the Arduino Serial Monitor, PuTTY or TeraTerm. Select a baud rate of 9600 (usually the default).

Type "vFFV" into the terminal and press Enter. All the LEDs should light up on the root board, indicating that it's all working properly. Typing "v00V" and pressing enter should cause all the LEDs on the root board to switch off.

If your tree has multiple boards, use a longer string such as "vFFFFFFV" (which suits three boards). Each hex digit corresponds to four LEDs so you will need two hex digits for each board in the tree.

If you don't supply enough hex digits, the furthest downstream boards will be fed old data from other upstream boards.

To use this board to drive a different SPI or I²C device, refer to Table.1 to figure out which connections on your device need to go to which pin on CON3 or CON4.

You can then set the baud rate to any of those mentioned under the "Two control modes" cross-heading above and then use a terminal program as described to send test commands and check the responses.

It's much easier to use the hexadecimal control modes initially to test the unit out, even if you're planning on using the binary SPI mode later.

Programming the PIC

If you have a blank PIC, you can program it using a PICkit 3 or PICkit 4, in conjunction with the MPLAB X IPE (Integrated Programming Environment) software. This is bundled with the MPLAB X IDE (Integrated Development Environment), which can be downloaded from **siliconchip.com.au/link/aalr**

Having installed it, launch the IPE program. From the Setting Menu, select Advanced Mode and log in using the default password. Click the Power button on the left and ensure "Power Target Circuit from Tool" is ticked.

Click the Operate button and select PIC16F1455 from the Device list, select your programmer from the Tool list and click Connect.

Once it indicates success, use the Browse button to select a source HEX file and open the HEX file from the software download file.

Connect the programmer to the PCB, ensuring that the arrowed pin on the programmer lines up with pin 1 (arrowed) on the PCB. Click the Program button and check that the messages in the bottom of the window indicate that IC1 was successfully programmed.

To test the chip, unplug the programmer and connect the board to a USB socket. Your computer should show that a new USB serial port has been detected.

Python program

We have provided a small example script written in the Python programming language to drive the LED Christmas Tree using this Interface Board. You will need some Python experience (or at least some script programming experience) to modify it. The Python language can be downloaded from **www.python.org/downloads/**

You will also need the pyserial library to access the serial port. This can be added by running the following command from the Python command line:

```
pip install pyserial
```

Download the program, "Serial Tree.py", from the SILICON CHIP website and change the port name to suit your system (eg COMx on windows, /dev/ttySx on Mac/Linux), and then run the program using the Python interpreter. It generates random patterns to give a twinkling effect. SC

A Home-Grown Aussie Supercomputer

DownUnder GeoSolutions' supercomputer in Perth is up there with some of the fastest in the world, and it was all done in Australia by Australian engineers and physicists. This story isn't just about a supercomputer; it's also about the hunt for oil and gas deposits underground using seismic surveys.

It might not always be apparent but the power of computers, and supercomputers in particular, is growing at a staggering pace.

Three years ago, in the July 2015 issue, we reported on the Pawsey Supercomputing Centre in Western Australia that housed Magnus, a supercomputer capable of 1.6 petaflops (1.6 million billion floating point operations per second) – see siliconchip.com.au/Article/8704

But it has already been overshadowed by a home-grown computer built by DownUnder GeoSolutions (DUG) also in Perth, Western Australia, which has a theoretical speed of 22 petaflops. That's 22,000,000,000,000,000 calculations per second!

Since the two computers are optimised for different roles, it's difficult to directly compare them. But by any measure, the DUG supercomputer is very fast. And it was built in-house at a fraction of the cost of the Pawsey facility.

It's hard to get your head around how much computing power a petaflop represents.

Think of it this way: the DUG supercomputer does its calculations about a million times faster than your desktop computer could. So a calculation that would take the supercomputer one minute would take two years on your computer.

To build a supercomputer of this power, you need to be innovative. DUG are using standard hardware with Intel's top-of-the-line processor designed for cluster computing, the Intel Xeon Phi.

What's innovative is that these are submerged in huge tanks of dielectric fluid which draw the heat away while providing near-perfect electrical insulation.

If you have a limited budget, you also need to be pragmatic, so the Intel chips are mounted in standard server racks (immersed in the fluid) and a standard 10Gb/s network is used to interconnect them. This is all housed on the ground floor of an ordinary office building in West Perth.

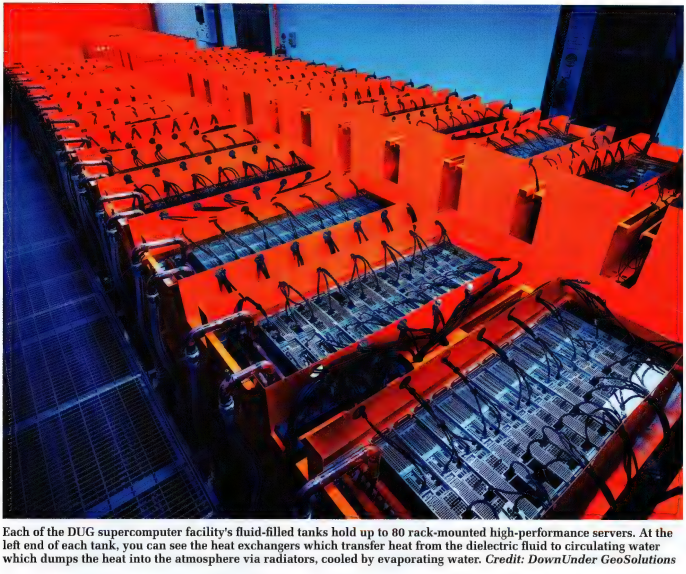
DownUnder GeoSolutions specialise in analysing geophysical seismic data and, using their enormous computing power, they can generate accurate three-dimensional maps of the rock strata under the surface.

These allow geoscientists to precisely locate possible oil and gas deposits, potentially saving hundreds of millions of dollars in failed drilling attempts.

By Geoff Graham

Seismic Surveys

The technology behind seismic



Each of the DUG supercomputer facility's fluid-filled tanks hold up to 80 rack-mounted high-performance servers. At the left end of each tank, you can see the heat exchangers which transfer heat from the dielectric fluid to circulating water which dumps the heat into the atmosphere via radiators, cooled by evaporating water. ***Credit: DownUnder GeoSolutions***

surveys is just as interesting as the supercomputer used to process the data. In simple terms, sound waves are created in the rock and the reflections (or echoes) from the layers under the surface are recorded. This can be done on the ocean or on land and the work that DUG does is evenly split between the two.

A marine survey involves an oceangoing survey vessel towing multiple lines of hydrophones behind it. These are called streamers and there could be up to ten streamers, each up to 12km long, with as many as 10,000 hydrophones being towed.

Every ten seconds, a sequence of air guns on the rear of the boat fire, creating a shaped sound wave through the water. When this wave hits the sea bottom, part of it travels through to the various rock layers underneath and on hitting them, is reflected back to the hydrophones.

Considering the huge number of multiple reflections from the ocean bottom and rock layers, and that there can be up to 10,000 hydrophones, and that this repeats every ten seconds, you get a sense of the mass of data that is recovered.

A full survey can take months of continuous seismic shots so the DUG supercomputer must process hundreds of terabytes of data and condense it into something meaningful.

This is why they needed to build one of the fastest supercomputers in the world. Even with their awesome computing power applied to the task, processing the data from a single survey can take months.

A land survey typically results in a smaller data set but it can require more intense number crunching. In this case, microphones are planted in the soil and a truck will thump (or vibrate) a huge iron plate placed on the ground. The ground reflections are recorded and the truck moves a short distance to thump again.

Land surveys generally cover a small area but the density of data recorded can be very large so these also take a lot of supercomputing time to process it.

Processing the data

Because of the amount of data involved in a survey (hundreds of terabytes up to a few petabytes), it is not feasible to transfer the data over the internet or communications lines.

Instead, it is recorded onto many tape cartridges of up to 10TB each and couriered to the processing centre. You could call it an alternative high-bandwidth network (often referred to as a "sneakernet"!).

The first task is to eliminate noise in the data created by ocean waves, wind, surface conditions etc and specialised software routines are used for this.

Then the multiple reflections from the surface and other layers need to be merged and more specialised routines are employed for this.

The data analysis and reduction then commences, using many mathematical techniques such as Kirchhoff migration, reverse time migration and full waveform inversion.

As part of the processing, DUG's own specialist geophysicists will calibrate the processing parameters to achieve the best result, which can highlight and locate the various rock strata to within one metre.

The ultimate output is a high-resolution 3D image and velocity model of the various underground layers which the customer's geoscientists can use to locate the optimum drilling locations (see below). At a cost of up to $100 million per drill hole, the savings of having an accurate picture of the underground geology can be huge.

Without accurately processed and imaged seismic data, an oil and gas exploration company could waste a lot of money on failed drilling attempts.

As with all supercomputers these days, the DUG supercomputer comprises thousands of individual processors, each of which is given a small segment of the overall job to work on.

A supervisor program running on a separate computer allocates these subjobs and tracks when each is completed. It then assembles all these individual results into the complete picture.

Innovative cooling

The basic computing unit in the DUG supercomputer is a "tank". This is a large iron tank, painted bright orange and filled with hundreds of litres of polyalphaolefin (PAO) dielectric fluid.

This is a synthetic base oil stock used in the production of high-performance lubricants. It looks and feels like a clear oil but it is non-toxic, non-flammable, biodegradable, has low viscosity, and most importantly, is an excellent insulator.

Each tank holds up to 80 rack-mounted high-performance servers which are immersed in the fluid. This includes the Ethernet connections, the power supply, 230VAC mains cables etc. The whole lot is completely submerged in the fluid.

The fluid is a far better conductor of heat than air and removing the heat from thousands of processors is not an easy task. Immersed in each tank is a heat exchanger which transfers heat from the fluid to circulating water, which in turn dumps the heat into the atmosphere via outside radiators, which are cooled by evaporating water.

A more traditional computer installation uses fans in each server unit to transfer the heat to the air and then large aircon units to extract the heat from the air. The fans alone consume a lot of power and the air conditioners are not very efficient so quite a lot of energy (which equates to money) is wasted in just removing the heat.

When you enter the room housing the DUG supercomputer, this point is driven home by the relative quiet in the room. A traditional data centre is deafening with thousands of fans pushing the air around but inside the DUG computer room there is just a subdued hum of ancillary equipment – the many servers doing the real work are strangely silent.

Power efficiency

When you consider the advantages of immersion, cooling you wonder why more supercomputers do not use the technique. For a start, with a power bill of millions of dollars a year, cutting that bill by 45% makes a huge difference.

The energy efficiency of data centres is commonly rated by a measure called the Power Usage Effectiveness (PUE) which typically is between 1.2 for a very efficient site to 1.4 for a more normal data centre.

That means that 20% to 40% of the power entering the data centre is being used for cooling, lights and other ancillary equipment.

The DUG supercomputer centre achieves a PUE of 1.04 which is close to the theoretically perfect score of 1.0.

Another advantage of the fluid bath is that all components of the server are held at an even 33-36°C. Nothing is heat stressed, especially the processors which can run much faster due to the fluid being so good at transporting the heat away.

The fluid also stops oxidation of all electrical joints (for example, the memory sockets) and prevents dust gathering on components; so they fail less often, resulting in better reliability.

About the only downside of the full immersion cooling technique is the rather messy job of removing a server unit for repair or upgrade. The fluid has a low viscosity, so a small amount goes a long way – but at least it is non-toxic and there are always plenty of paper towels on hand.

A close-up of the servers silently computing in their liquid heaven. They are immersed in a polyalphaolefin dielectric fluid, a synthetic base oil stock used in the production of high-performance lubricants and is an excellent electrical insulator. *Credit: DownUnder GeoSolutions*

Server units

In the DUG supercomputer, each processor (an Intel Xeon Phi – see explanatory panel) is housed in a standard rack-mounting server unit manufactured by companies such as SuperMicro, Gigabyte and Intel. DUG removes the fans and the thermal paste on the central processing unit (CPU) but otherwise, they are standard off-the-shelf units.

Then the whole lot is submerged in the dielectric fluid. It is quite unsettling seeing the mains power cord dive into the fluid but it is such a good insulator that everything works perfectly.

As you peer into the tank, you can see down in the depths various LEDs on the motherboards still blinking on and off as the CPUs silently compute in their liquid heaven.

The processor currently used by DUG is the Intel Xeon Phi 7250 and they use so many of this series of chips that DUG has become Intel's largest commercial customer for them.

The Phi processor is designed for use in supercomputers, servers and workstations, and with a retail price of about 2,000 USD and up each, it isn't cheap.

The Xeon Phi's most important characteristic is that it has the hardware for doing operations on arrays of floating point numbers (add, multiply etc) – each core can do up to 64 floating point operations per clock cycle.

Most of the work in analysing the survey data uses just these functions, so the fact that they are implemented in silicon (versus software) is a significant speed advantage.

The Xeon Phi grew out of an earlier design by Intel for a GPU (Graphics Processing Unit) and it shares many of these characteristics. GPUs from companies such as Nvidia are popular in many supercomputing applications because they are effective at operating on arrays of numbers.

The difference with the Xeon Phi is that these operations are in floating point (most GPUs can do floating point operations but generally only on "single precision" values) and the chip can also run standard software such as Linux, so a separate "standard" processor is not needed to control it.

Each chip contains up to 72 processing cores, running at up to 1.6GHz with super high-speed memory. With the hardware floating point and array processing power, it is very efficient at processing the sort of data that DUG works with. With about 8,000 of these in their supercomputer, they have a lot of processing power.

The immersion cooling also offers another advantage: because of its efficient removal of heat, the chips can run forever at their top turbo speed without throttling back due to excessive temperatures, as would normally be the case with air cooling

Networking

Each server is connected to a 10Gb/s Ethernet network via standard, off the shelf Ethernet switches. Because each processor can spend a lot of time working on just one job (up to a week), the demands on the network are not huge even though there are a lot of connected processors.

Note that other supercomputers use much faster and more complicated networking arrangements for good reason; there are certain computing jobs which involve lots of inter-node communications and they would run slow on DUG's network; but that is not what the DUG computer was designed to do.

Throughout the network, the operating system used is a heavily modified version of Linux. The non-critical sections of the processing software are written in Java but the time-critical sections are written in optimised C.

It is worth remembering that all of this, including the all-important software, was developed and built in-house.

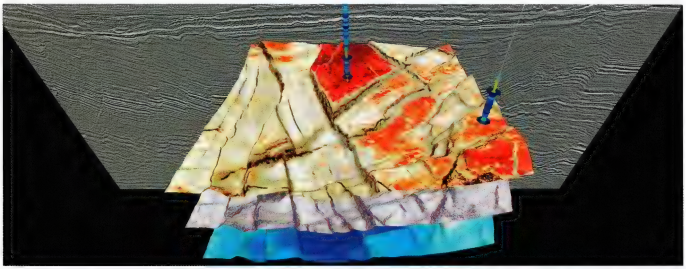
This supercomputer is pragmatically designed using standard components and is not the product of a well-funded government program.

Innovation

DownUnder GeoSolutions must rate as one of Australia's most innovative companies.

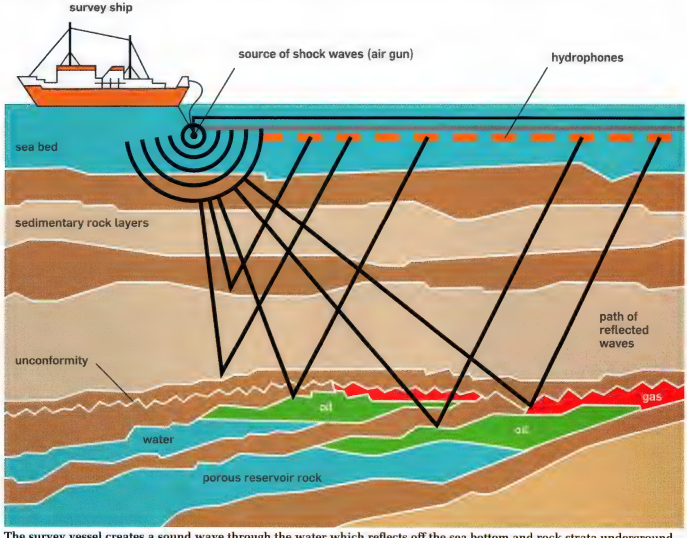
Started by two friends fifteen years ago in a garage (as most great companies seem to do) they have grown to be the third-largest company in their field, with 350 employees; mostly specialists, such as geophysicists, mathematicians, physicists and software developers.

They have offices worldwide and supercomputer facilities in Houston,

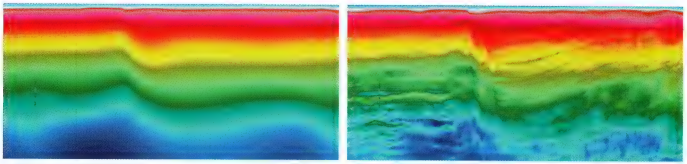


The supercomputer outputs a high-resolution 3D image and velocity model of the various underground layers which the customer's geoscientists can use to locate the optimum drilling locations. At a cost of up to $100 million per drill hole, having an accurate picture of the underground geology is important. ***Credit: DownUnder GeoSolutions***

A marine survey vessel towing multiple lines of hydrophones. There could be up to 10,000 hydrophones being towed. Every ten seconds, a sequence of air guns on the rear of the boat fires, creating a shaped sound wave through the water which reflects off the sea bottom and rock strata underground. *Credit: Western-Geophysical-Seismic*



The survey vessel creates a sound wave through the water which reflects off the sea bottom and rock strata underground, back to the hydrophones being towed behind the vessel. A full survey can take months of continuous seismic shots so the DUG supercomputer must process terabytes of data. *Credit: KrisEnergy Ltd*



Full waveform inversion (FWI) is a technique to create high-resolution velocity models, in this case on a seismic waveform. The purpose of this transformation is to use the velocity model (data from the seismic survey) to determine what the underground structure would look like. The photos above show an initial velocity model (left) and then after FWI (right), the result being much closer to the actual seismic data. The FWI technique used by DUG possibly makes use of a finite difference scheme or solutions to the Helmholtz equation among other mathematical techniques to determine the behaviour of the non-linear system (see www.researchgate.net/publication/268632261_Full_Wave_Inversion).
***Image source:* www.dug.com/services/full_waveform_inversion_fwi/**

London, Kuala Lumpur and of course Perth, which is their largest supercomputer and also their headquarters.

Despite the cooling off of Australia's resources sector, Perth is still one of the world's premier centres for mining, oil and gas exploration.

As an illustration, it is estimated that 70% of the world's mining software is developed in Western Australia. Perth also services the many oil and gas companies exploring the North West Shelf fields as well as other reserves such as in Bass Straight.

Houston in the USA (Texas) is another world centre for oil and gas exploration and London is a major financial centre, as well as servicing the North Sea.

Often, the data produced by the exploration teams is restricted to one part of the world due to sovereignty and security concerns and this is one reason why DUG needs four supercomputing centres.

Another reason is that the company works closely with its clients when analysing the data and it is handy to be close to them.

What's in the future for DUG?

With 56 tanks and about 8,000 processors, the West Perth supercomputer facility rates somewhere in the top 50 or so known supercomputers in the world.

Shadowy government intelligence agencies such as the NSA or our own Australian Signals Directorate likely have even more powerful supercomputers for jobs like cracking encrypted messages, but the secrecy involved means that we do not know of them.

However, commercial pressures continually demand more processing power. One of the more important processing techniques called Full Waveform Inversion (FWI) demands enormous computing time.

An important FWI parameter is frequency measured in hertz and processing is commonly done at 5Hz to 25Hz but DUG want to drive towards 125Hz.

The problem is that when you double the frequency, you need 16 times the computer power to get the full benefit. A higher resolution would result in much higher accuracy 3D imaging and models and these would be eagerly received by DUG's customers and provide a clear advantage in this competitive industry. To attain this target, DUG is planning to build a 722 tank facility in Houston.

Compare this to the 56 tank (approximately 8,000 processor) supercomputer in Perth and you can see the vastness of the task. When completed, the Houston supercomputer could be one of the five largest known supercomputers in the world.

Other than the multitude of tanks and processors involved in the proposed Houston facility, there are many other challenges to be overcome. These include the network bandwidth required and the practical problem of managing and tracking the status of so many processing units.

The reason why Houston was selected for this supercomputer is simple: the cost of electricity. In Perth, the commercial cost of power is about 15c/kWh while in Houston, it is 4.7c/kWh. With an annual power bill in the tens of millions of dollars, that makes a huge difference.

Regardless, the supercomputer will be designed and managed in Australia and that is something that all Australians can be proud of.

The world's top supercomputers

(1) Summit (122 petaflops)
Summit is an IBM-built supercomputer running at the US Department of Energy's Oak Ridge National Laboratory. It has 4608 nodes, each with by two IBM Power9 22-core CPUs and six Nvidia Tesla V100 GPUs.

(2) Sunway TaihuLight (93 petaflops)
This is a supercomputer developed by China's National Research Center of Parallel Computer Engineering & Technology and installed at the National Supercomputing Centre in Wuxi (Jiangsu province). It uses 40,960 Chinese-made SW26010 256-core CPUs (plus four auxiliary cores) running on a custom operating system.

(3) Sierra (71 petaflops)
Sierra is an IBM supercomputer at the USA Lawrence Livermore National Laboratory. It has an architecture similar to that of Summit, with each of its 4320 nodes containing two Power9 CPUs plus four Nvidia Tesla V100 GPUs.

By way of comparison, the DownUnder GeoSolutions supercomputer in West Perth has a theoretical performance of 22 petaflops. Unlike the above-listed supercomputers, this has never been tested, simply because running the benchmark would take about seven days and that would be expensive for DUG in terms of lost production. *(source: www.top500.org)*

What is the Intel Xeon Phi?

Xeon is the name given to Intel's line of processors intended for servers. Many Xeon processes are essentially just "beefed up" versions of their desktop processors, with higher clock speeds, more cores and so on. But the Xeon Phi is a different beast altogether as it is specifically intended for use in computer clusters.

A typical laptop or desktop processor these days contains 2-8 processing cores (in some cases, more). There are two main uses for multiple processing cores: either when you are running more than one application at a time, in which case each application can run on its own dedicated core, or for applications optimised for multi-core processors, where they can split up their workload across multiple cores.

But multi-core optimised applications are the exception rather than the rule, partly due to the significant extra complexity required to split the work up amongst the cores, and partly due to the fact that some tasks are easier to split up than others.

Generally, it is very slow, computation-heavy tasks which are optimised for multiple cores. For example, video compression or 3D rendering.

Both of these tasks can take hours or days to complete and both are relatively easy to split up into smaller jobs (for example, compressing or rendering one quadrant of the video frame). So optimising them for multi-core processors makes a lot of sense.

But since so many applications are essentially "single-threaded" and will only occupy one core, laptop and desktop (and phone/tablet) processors are generally optimised for "straight-line speed", which requires a high clock rate and the ability for a core to execute as many instructions simultaneously as possible.

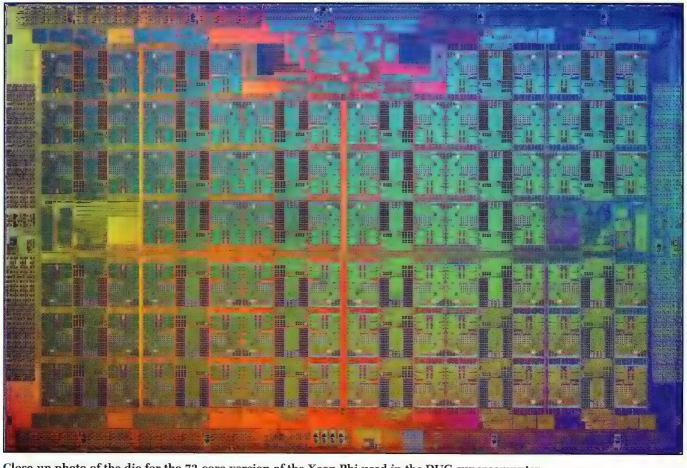
Multi-core optimisation

However, if you need to perform a huge number of computations then it starts to make sense to design the software to take advantage of more than a few cores. You want to split the job up across hundreds or thousands of processors. And in that case, the ideal processor design starts to look quite different.

For a start, the processor clock speed and "straight-line" execution speed are no longer important. If you can design a processor with twice as many cores, where each core runs at 60% of the speed, then you will have gained 20% additional total performance. That's assuming that splitting the job up between more cores has a very low overhead; as usual, there is a point of diminishing returns.

And lower clock speeds usually provide higher power efficiency, ie, more work done per watt consumed/dissipated. And that means less cooling; in many cases, heat dissipation/cooling is actually the limiting factor in computing density. So improving computational efficiency can result in a faster cluster.

Also, if reducing clock speed means that you can fit more cores on a single die, that's also a boon for inter-core communications, since communication with a core on the same die is much faster than communication with a core on another die, which in turn is



Close-up photo of the die for the 72-core version of the Xeon Phi used in the DUG supercomputer.
Image source: *https://seekingalpha.com/article/3738586-intel-selling-stack-knights-landing*

much faster than communication with a core in a separate chip or in a different chassis.

And depending on the type of computations being made, it may be the case that communications are the limiting factor on performance, not raw number-crunching ability.

So for all these reasons and more, if you design a processor from scratch to be used in a cluster-type environment, its performance in that role can be dramatically improved.

Enter Xeon Phi

Like a standard Xeon, and most Intel desktop/laptop processors, the Phi executes x86-64 code. That makes it easy to develop software for. But it has many more cores than a typical processor; the number varies with the exact version but there are usually 64-72 cores per processor.

This specific line of Xeons, codenamed Knight's Landing, utilises Intel Atom cores (Silvermont) with many major modifications to the architecture. The Atom line of chips is known primarily for low-power, low-voltage applications like laptops and systems on a chip (SoC).

These cores also have 'hyperthreading' type technology, which allows around 256 threads of code to be executing simultaneously, however, since many of these share execution units, the overall increase in computing power from this threading feature is modest. Hand-optimised code potentially performs better with hyperthreading disabled. Clock speeds range from just over 1GHz up to 1.7GHz in the latest models.

Each chip has a relatively large amount of shared cache memory (around 34MB) along with smaller caches dedicated to each core. Their external RAM interfaces are two-tiered, with up to 16GB of very fast MCDRAM (400+GB/s; normally mounted inside the chip) and up to 384GB of DDR4 (102.4GB/s; six channels on the motherboard) per chip.

All this results in a speed rating of around 3 teraflops per processor, with a dissipation of around 230W. The power efficiency is 13.04GFLOPS/W (3TFLOPS ÷ 230W).

Compare that to a standard high-end Xeon, for example, an E5-2697A v4 which has 16 cores, runs at up to 3.6GHz and dissipates up to 145W, giving a performance of around 480-640GFLOPS (depending on how it's measured). That gives a power efficiency figure of 4.4GFLOPS/W (640GFLOPS ÷ 145W) for a retail price of 3000 USD.

When a supercomputer cluster's power consumption is measured in the megawatts (and with the price of electricity these days), you can see how the much higher power efficiency of the Phi processor – around three times that of the standard Xeon – would be a great benefit.

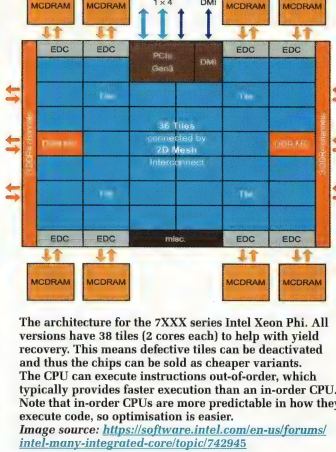
Part of the reason for this improvement is the fact that not only does the Phi have many more lower-clocked cores but they are capable of doing more operations per clock with highly parallel instructions.

AVX-512 Instruction set

Modern standard Xeon processors support the AVX2 SIMD (single-instruction, multiple-data) instruction set, which allows for up to four single-precision floating point or two double-precision floating point operations to be executed per pipeline.

The Xeon Phi processors used by DownUnder GeoSolutions support AVX-512 instructions, which can perform eight single-precision floating point or four double-precision floating point operations per pipeline.

Note that in both cases, each core has multiple floating point pipelines and each processor has a large number of cores.



The architecture for the 7XXX series Intel Xeon Phi. All versions have 38 tiles (2 cores each) to help with yield recovery. This means defective tiles can be deactivated and thus the chips can be sold as cheaper variants. The CPU can execute instructions out-of-order, which typically provides faster execution than an in-order CPU. Note that in-order CPUs are more predictable in how they execute code, so optimisation is easier.
Image source: ***https://software.intel.com/en-us/forums/intel-many-integrated-core/topic/742945***

So the number of calculations that can be processed per clock is huge, and the number of clock cycles per second is counted in the billions.

So it's no wonder that these chips can perform a huge number of calculations per second; a large cluster can contain thousands of such chips.

Some of the important instructions supported by this CPU include:

VREFETCHWT1
– Prefetch cache line into the L2 cache with intent to write
VEXP2 {PS,PD}
– Approximate 2^n with maximum relative error of 2^{-23}. Used on transcendental sequences.
VRSQRT28 {PS,PD}
– Approximate reciprocal square root ($1 \div \sqrt{x}$) with maximum relative error of 2^{-28} before rounding. Used in digital signal processing to normalise a vector.

The Xeon Phi is being discontinued by 2019, with the 10nm refresh cancelled and the current product line no longer being sold or replaced after 2019.

This is likely due to competition from Nvidia, production woes in shrinking the fabrication processes and/or due to their push again to produce a discrete graphics processor unit (GPU).

For more information, see the Xeon Phi Wikipedia page: **https://en.wikipedia.org/wiki/Xeon_Phi**

Intel's developer page on Xeon Phi is at: **siliconchip.com.au/link/aal4** **SC**

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Dual mode digital dice

Rolling two six-sided plastic dice is common in many popular board games, such as Monopoly.

This circuit simulates rolling two such dice using pseudo-random number generator code in a microcontroller and displays the result pictorially on a 16x2 alphanumeric LCD. Custom display characters are used so that the screen can show pictures of the dice being rolled.

You can see a video of the unit, showing both modes, at: https://youtu.be/dkCm1H0fGYw This shows how easy and quick it is to use, compared with rolling actual dice, which have a habit of falling off the table and onto the floor if you are a bit too vigorous with them!

Besides the ATmega8 microcontroller and the LCD screen, there isn't much else to the circuit; just a piezo buzzer which sounds beeps while the dice are being "rolled", two buttons (one to roll and one to change mode), a contrast adjustment pot for the LCD, a power switch and a couple of resistors. The circuit runs from a 5V supply, which could be from a USB charger or portable power bank.

The LCD is driven in four-bit mode from digital outputs PD0-PD3 of IC1 (for data) and PD4-PD5 (for control). A 150Ω backlight current-limiting resistor determines the LCD backlight brightness.

The two pushbutton switches connect between digital inputs PC1/PC2 of IC1 and ground, with internal pull-ups enabled on these pins to define a high digital state when the buttons are not being pressed.

Operating it is simple. After you have switched it on, simply press pushbutton S2 to roll the dice. You will see the dice move around on the LCD screen and the piezo buzzer produces some beeps, then the dice will settle on their final values which remain on the screen for as long as you want. Then you can press S2 to roll them again.

A short press of S3 toggles between the two modes; in the default mode, each die is represented by a single box with between one and six dots, along with a numeral showing the number of dots for clarity.

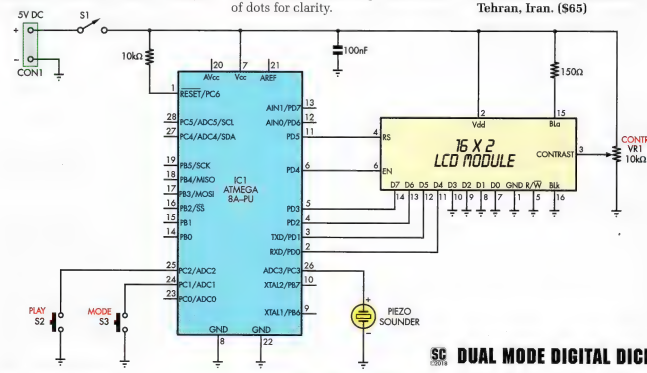
In the alternative mode, each die is represented by a stack of dice, starting with a "one" and then a "two" and so on, up to the value which was rolled (see the video for more details).

So the two modes are visually different but perform much the same task, of generating two random whole numbers in the range of one to six.

The software is written in BASIC and compiled to a HEX file using BASCOM AVR (a free trial of this software is available). Both the BASIC source code and HEX file can be downloaded in a zip package from the Silicon Chip website and the HEX file can be uploaded into a suitable chip using any standard AVR programmer.

The code makes use of the "Deflcdchar" feature of BASCOM to define custom LCD characters, and the Rnd() function to generate pseudorandom numbers for dice rolling. The random number seed variable (___rseed) is initialised with the value of TIMER0 so that the results are different each time the unit is powered up.

Mahmood Alimohammadi, Tehran, Iran. ($65)



SC 0308 **DUAL MODE DIGITAL DICE**

Super-simple headlight-on reminder

If you have an older vehicle, it may be possible to leave the headlights on even after you've removed the ignition key.

It doesn't take long for the headlights to drain the battery and it's really annoying when your car won't start. But if you do this regularly, it can be costly since it will ruin the battery.

This circuit will sound an alarm if you forget to switch the headlights off and it doesn't get much simpler than this.

It uses just two components plus some wiring. The wiring should not be difficult to run, as all the necessary connections can be made under or near the steering column on most vehicles.

When the headlights are switched on, current can flow from the COM contact of RLY1 to the NC contact and then to the piezo buzzer, causing it to produce a sound.

But as soon as the ignition switch is turned, powering the accessory (ACC) power supply, the coil of RLY1 is energised, disconnecting the piezo buzzer and so it falls silent.

If you switch the ignition on before turning on the headlights, the buzzer will never have a chance to sound.

But if you switch the ignition off and forget to turn the headlights off first, then RLY1 will be de-energised and it will make a noise. That will remind you to switch the headlights off, saving you from a coming back to a flat battery.

The headlight switch typically interrupts the +12V battery supply (since the vehicle chassis is generally used as a negative return these days) but very old vehicles may have a positive chassis and may switch the negative side instead.

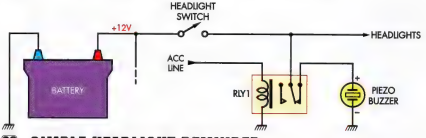
In this case, you just need to reverse all the connections. The ACC line will presumably also be switched on the negative side, since the relay coil is non-polarised it can be connected either way.

Then the NC contact would go to the negative end of the piezo buzzer, with the positive side going to chassis also.

The relay should be a DC coil type with a coil voltage that suits your vehicle battery (ordinarily 12V but very old vehicles may be 6V).

The contact rating does not need to be high as it will only be conducting a few tens of milliamps at most.

Warren Goninan,
Cobar, NSW. ($50)



SC 080078 **SIMPLE HEADLIGHT REMINDER**

YOU ASKED FOR IT . . . WE'VE DELIVERED!

The Vintage Radio Collection from the pages of SILICON CHIP

"Vintage Radio" is one of the most popular columns which appears every month in Australia's most-read and authoritative electronics magazine, SILICON CHIP.

Over the years many readers have asked us if there was a single source for all "Vintage Radio" articles so a particular set or sets they have managed to get hold of could be referenced. Until now, that was not possible.

But now it is!

We've put together a DVD# containing every "Vintage Radio" column for more than 20 years – from April 1997 right through to December 2018 – and included an easy-to-read index so you can find the one you're looking for. They're all provided in PDF format so the quality is even better than in the magazine (you can actually read many dials!). And there's much more than radios – there's articles on vintage TVs, amplifiers... all from a bygone era!

Physical DVD:
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#To view, requires Adobe Acrobat on your computer (free to download): **https://get.adobe.com/reader/**
Cannot be used with an audio DVD Player

Exclusively available from SILICON CHIP: www.siliconchip.com.au/shop

Simple mains soft starter

This circuit performs much the same function as the Soft Starter project published in the April 2012 issue (siliconchip.com.au/Article/705).

Both devices are very handy for preventing high current surges when switching on devices with large switchmode power supplies (see the 2012 article for more details). But this version takes a slightly different approach to limiting inrush current.

Like the aforementioned Soft Starter, it switches a set of relay contacts after a time delay to reduce the amount of wasted energy after it has done its job limiting the inrush current, which occurs within the first second or so after mains power is applied.

When mains power is first applied, the current delivered to the load(s) is limited because it flows from the incoming Active conductor to the load through four 47Ω 10W resistors in a series/parallel configuration.

These resistors act like a single 47Ω 40W resistor and with a peak mains voltage of around 325-350V DC, the current limit is 7.5A (350V ÷ 47Ω).

A small amount of current also flows through the 1µF X2 capacitor and into the bridge rectifier formed by diodes D1-D4, charging up the 4700µF electrolytic capacitor.

Its charging rate is limited by the impedance of the X2 capacitor and the voltage across the 4700µF capacitor reaches the threshold to energise the coil of RLY1 after about one second.

When the relay switches, its contacts short out the four 47Ω resistors, applying the full mains voltage to the load and allowing those resistors to cool down.

In case there is a fault which prevents the relay from switching, the 47Ω resistors will continue to heat up and this will result in the thermal fuse which they surround going open-circuit, cutting power to the circuit and the load. This prevents any further damage from occurring.

A neon indicator is provided which switches on after the initial ~1s delay, to indicate that the relay has switched and the unit is working normally.

Zener diode ZD1 protects the 4700µF electrolytic capacitor from being over-charged in the case of transient high mains voltages or spikes, while the 47Ω resistor in series with the 1µF capacitor limits its inrush charging current when mains power is first applied. The 220kΩ resistor across the 1µF capacitor discharges it quickly when mains power is removed.

During normal operation, ZD1 does not conduct since the 1µF capacitor has an impedance at 50Hz of about 3.2kΩ, so it will supply around 71mA (230VAC ÷ 3.2kΩ) while the coil of RLY1 draws 75mA at 12V. So the voltage across the coil will not usually

Freezer temperature monitor and alarm

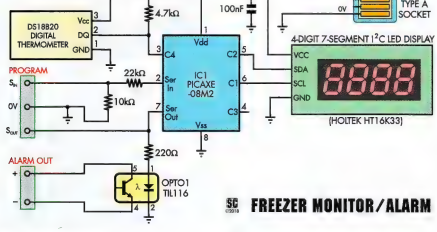
This circuit provides an easy-to-read and accurate temperature reading for a fridge or freezer and can also sound an alarm if the temperature is too high.

It's based on a PICAXE 08M2+ microcontroller (IC1) and a Holtek HT16K33 four-digital I²C LED display.

In normal operation, the device sequentially displays five temperature values (to one decimal place), being: ambient temperature, the highest temperature reading in the last 24 hours, the highest temperature since the last device reset, the lowest temperature in the last 24 hours and the lowest temperature since the last device reset.

Before each reading is shown, the display indicates which temperature is about to be displayed using a code on the LCD. It shows "t" for the current temperature, "Hi" for highest temperature 24 hours, "rHi" for highest temperature since reset, "Lo" for lowest temperature in the last 24 hours and "rLo" for the lowest temperature since the last reset.

OPTO1 provides the ability to generate an alarm if necessary. For example, you could connect a piezo buzzer or siren to either the pins on the alarm header, with an appropriate voltage source and then if the temperature goes too high, the sound will alert you.



SC 03910 **FREEZER MONITOR/ALARM**

At power-up, the display shows the alarm ("AL") value as programmed into the software for a few seconds before beginning normal operation.

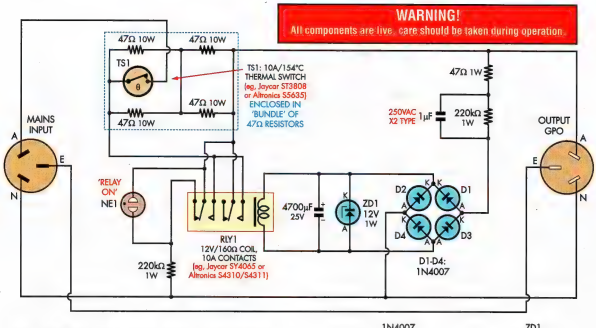
This is the temperature threshold above which OPTO1 is triggered. At the same time, the LED display is set to blink once the temperature goes above the alarm threshold. To stop the alarm, you need to reset or power cycle the device.

This feature is handy if there was, for example, a blackout while you were away. Food can be spoilt and then refrozen and you might not be able to tell otherwise.

The temperature reading comes from a DS18B20 digital temperature sensor. You can get these in a small TO-92 plastic package or encapsulated into a waterproof probe with a three-core lead attached.

But the cables on the waterproof probes are usually quite thick; I soldered a TO-92 package DS18B20 sensor to the end of a length of ribbon cable and sealed inside some heat-shrink tubing.

The flat ribbon cable is much easier to get past the rubber sealing gasket around the outside of the fridge/freezer



SILICON CHIP SIMPLE MAINS SOFT STARTER

reach 12V due to the limited current flowing through the 1µF capacitor.

All components in this circuit are live when it is plugged in so the whole thing must be fully insulated and enclosed within a suitable box.

The incoming and outgoing Earth wires (if separate) must be joined with a double-screw BP connector for safety.

Warwick Talbot,
Toowoomba, Qld. ($65)

door, without compromising its sealing ability.

Note that there are no pull-up resistors in the circuit for the I²C serial lines (SDA and SCL) to DISP1; the 4-digit display board already incorporates suitable pull-up resistors.

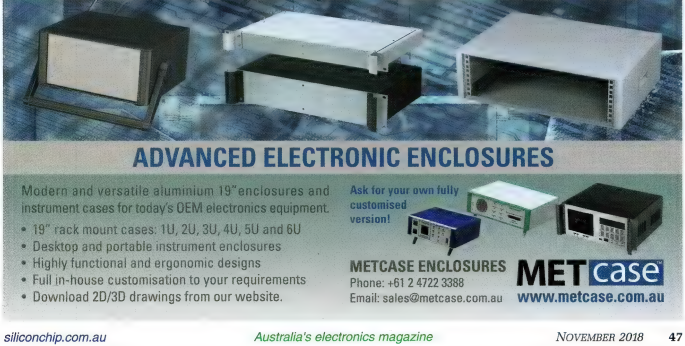
The software is quite simple. A few I²C commands are sent to the display to initialise it, then commands can be sent containing data representing the four digits to be displayed.

The HT16K33 also has some handy features that include display dimming and display blinking. You can change the dimming value in the software if you don't want the display to run at full brightness.

The BASIC code ("fridge_freezer_monitor.bas") can be downloaded from the SILICON CHIP website and then uploaded to IC1 using a PICAXE USB programming cable, connected to the programming socket provided.

Since the chip only has eight pins, pin 7 shares two functions. It is used for programming and also to power the LED in OPTO1 when the alarm condition occurs. For this reason, it's best to disconnect anything connected to the alarm output before programming.

David Worboys,
Georges Hall, NSW. ($70)



Satellite TV polarisation indicator

Satellites transmit signals in two different polarities (horizontal and vertical). This allows the bandwidth to be effectively doubled, by transmitting two different signals in the same frequency band.

A low-noise block (LNB) is the receiving device attached to a satellite dish. Because the signals with different polarities occupy the same frequency band, the LNB can only send one of the two signals down a single coaxial cable.

A single-output LNB is typically powered from the receiver set-top box via a DC voltage applied to the coaxial line. The level of this DC voltage is also used to signal the LNB as to which polarity the decoder wants to receive. For receiving vertically polarised signals, the receiver delivers around 13V while for horizontally polarised signals, it delivers about 18V.

North America uses a different system called circular polarisation, which shares this voltage signalling method, using 13V for right-hand polarisation and 18V for left-hand polarisation.

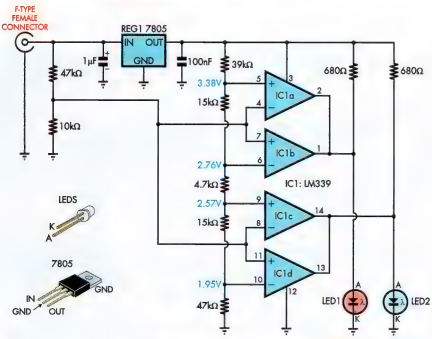
When this circuit is connected to a satellite system coaxial cable, it indicates the currently selected polarity based on the DC voltage level, by lighting one of two LEDs. The circuit is itself powered by the DC voltage on the cable; no external power supply is required.

This circuit useful for satellite system installers and technicians. You could measure the cable voltage using a DMM but using this circuit makes the job much easier. It can be used to diagnose domestic systems as well as more complex commercial installations.

The centre pin of the F-Type connector feeds the input of the 7805 voltage regulator (REG1) and a resistive voltage divider, formed by 47kΩ and 10kΩ resistors. This reduces the voltage from the cable by a factor of 5.7, so the voltage at the junction of the resistors is below 5V, as required by the following circuitry.

This reduced voltage is then fed to the inverting input pins of comparators IC1a and IC1c, and the non-inverting input pins of comparators IC1b and IC1d. These are all contained within a single low-cost quad comparator chip.

The four sections of quad comparator IC1 are configured as two window comparators. A string of five resistors, connected between the 5V rail and ground, produce the upper and lower threshold reference voltages for each window comparator. The approximate voltages are shown on the circuit diagram.



SC 03018 **SATELLITE TV POLARISATION INDICATOR**

Looking at IC1a and IC1b first, taking into account the 5.7 times division ratio of the input divider, the output of the window comparator will be high and LED1 will light when the cable voltage is between 15.73V (2.76V × 5.7) and 19.27V (3.38V × 5.7).

Our 18V nominal figure for a horizontally polarised signal is close to the middle of this range, so LED1 should light when vertical polarisation is selected. The rest of the time, one of the comparator outputs will be low and LED1 will be off.

In more detail, if the cable voltage is above 19.27V, the voltage at the inverting input of IC1a (derived from the cable voltage) will be above the reference voltage and so IC1a's output pin will go low, effectively shorting out LED1 and preventing it from lighting.

A similar situation occurs with IC1b if the cable voltage is below 15.73V; IC1b's output will go low, also shorting out LED1.

But if the cable voltage is between these two values, neither comparator output is low and so current can flow from the 5V supply, through the 680Ω current limiting resistor and LED1, lighting it.

The same arrangement applies for IC1c, IC1d and LED2 except that the thresholds are 2.57V (14.64V) and 1.95V (11.10V). So LED2 will light if the cable voltage is close to 13V. If it's below 11.10V, above 19.27V or right in the middle of the two ranges (14.64V-15.73V) then neither LED will light.

The reason why the windows are quite large, giving a volt or two leeway on either side of the nominal voltages, is that I have found significant voltage variation between different models of satellite decoders.

Note that when vertical indicator LED2 is lit, you may observe the horizontal polarisation indicator LED (LED1) blinking on occasion. This is due to the satellite decoder sending a 22kHz pilot square wave to the LNB. The pilot signal tells the LNB which frequency range it should be receiving.

The circuit will not disturb the L-band RF signals if connected to an active system, so you can still decode TV/radio channels.

Luke Staudinger,
Sydney, NSW. ($50)

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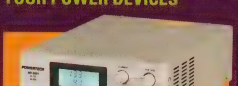

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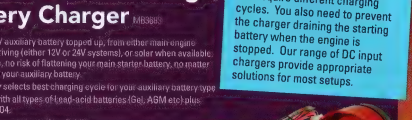

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- Requires six digital inputs
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REF: SILICON CHIP MAGAZINE NOV 2013

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SKILL LEVEL: BEGINNER
TOOLS: SOLDERING EQUIPMENT, HOT GLUE OR BLUETACK

WHAT YOU NEED:

DUINOTECH LEONARDO BOARD XC4430 **$29.95**
GPS RECEIVER MODULE XC3712 **$49.95**
240 X 320 LCD TOUCH SCREEN XC4630 **$29.95**

Finished project. Cable not included

VALUED AT **$109.85**

NERD PERKS CLUB OFFER
BUY ALL FOR **$84.95**
SAVE 20%

SEE OTHER PROJECTS AT:
www.jaycar.com.au/arduino

NEW 2015

FROM **$39.95**

ILLUMINATED ROCKER SWITCH PANELS SZ1923

Switches are rated at 20A for a 12V system (10A for 24V) up to a maximum 45A per panel. High quality. Blue LED illumination.

2 WAY SZ1923 **$39.95**
4 WAY SZ1924 **$59.95**
6 WAY SZ1925 **$79.95**

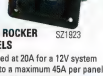
$39.95

300PC QC CRIMP CONNECTOR PACK PT4536

Contains the most commonly used quick connectors including bullet, ring, fork, spade and joiners in various sizes and colours.
See website for full specifications.

NEW 2015

$19.95 ea



ZD0764

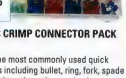
LED FESTOON REPLACEMENT GLOBES

Features a special "3D" type of LED lamp, which provides an extremely even, wide light output. 12VDC. Suitable for off-road use only.

31MM ZD0764
36MM ZD0766
41MM ZD0768

NEW 2015

FROM **$29.95**



SZ2031

BLADE FUSE BLOCKS WITH BUS BAR

Accepts up to 30A per output with handy fuse-blown indication. Negative bus bar.

6 WAY SZ2031 **$29.95**
12 WAY SZ2032 **$39.95**

FROM **$6.95**

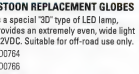
PP2090

MERIT CONNECTORS

Smaller in size, extremely rugged and provides higher reliability and current ratings.

15A UNFUSED PLUG PP2090 **$6.95**
8A PLUG WITH CIGARETTE LIGHTER ADAPTOR PP2094 **$6.95**
15A IN-LINE SOCKET WITH COVER PS2086 **$6.95**
15A PANEL SOCKET WITH COVER PS2082 **$9.95**

FROM **$6.95**



PP2150

WATERPROOF DEUTSCH CONNECTOR SETS

High quality connectors commonly used in automotive or marine applications. 13A rated.

2 WAY PP2150 **$6.95**
4 WAY PP2148 **$8.95**
6 WAY PP2148 **$9.95**

BREADBOARD POWER MODULE XC4606

Adds a compact power supply to your breadboard
Power from a USB socket or DC plugpack, 3.3V or 5V switchable.

$9.95

$14.95

BREADBOARD WITH 830 TIE POINTS PB8815

Ideal for electronic prototyping and Arduino® projects. Labelled rows and columns. Adhesive back for mounting.

- 200 Distribution holes
- 165(L) x 54(W) x 9(H)mm

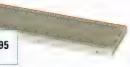
$29.95

LED PACK 100-PIECES ZD1694

Contains 3mm and 5mm LEDs of mixed colours. Even includes 10 x 5mm mounting hardware FREE!
See website for full contents.

- Red, green, yellow, orange LEDs

FROM **85¢**



HEADER TERMINAL STRIPS

- Vertical Pins
- 3A rated
- Snap apart to make any length

28 PIN HM3211 **$0.85**
40 PIN HM3212 **$0.95**

$4.95

HOOK-UP WIRE PACK WH3025

2 meters of 8 different colours.
16 meters in all.

- Stranded cable 13 x 0.12mm size

Quickcharge™ 3.0:

Up to 4x faster than a standard USB charger. Best for compatible Smart phones and Tablets.

FROM **$19.95**

USB CHARGERS

Mobile device charging solution for home and travel needs.

IN-CAR	MAINS
3A SINGLE MP3680 **$19.95**	**3A SINGLE** MP3443 **$29.95**
5.4A DUAL MP3682 **$29.95**	**3A DUAL** MP3437 **$39.95**

$79.95

10,000MAH DUAL USB POWER BANK MB3725

Huge 10,000mAh Li-Po battery supports powering and recharging your devices. Recharge the unit via USB Type-C or micro USB.

- 75(W) x 151(D) x 15(H)mm

Power Delivery:

Safer, higher power, faster universal charging, up to 70% faster than standard 5W charging. Great for new laptops, game consoles, phones and more.

FROM **$29.95**

USB TYPE-C MAINS POWER ADAPTORS

Intelligently feed maximum power for quick and optimum charging. USB Type-C with Power Delivery enables faster charging for more powerful devices.

- 100-240VAC @50/60Hz

18W MP3410 **$29.95**
45W MP3412 **$59.95**

$79.95

USB 3.0 TYPE-C HUB AND CARD READER XC4308

Expand the connectivity of your computer with this card reader and hub combo with USB Type-C plug and power delivery socket. Ideal for use with the MacBook® to maximise connectivity of its singular USB Type-C input.

- Up to 80Mbps USB transfer rate
- 81(L) x 52(W) x 15(H)mm

Wireless:

Entirely wireless method, no messy cables! Supports fast (10W) & standard (5W) charging.

Smartphone not included

WAS $39.95
$29.95
SAVE $10

WIRELESS QI CHARGER MB3667

Place your phone within a centimetre or two of the charging pad for automatic charging.

- LED indicator
- 88(Dia) x 20(H)mm

Suitable for iPhone 8 / 8 Plus, iPhone X, Samsung Galaxy Note 8 / S8 / S8 Plus, S7 / S7 Edge and Qi-Enabled Devices.

$49.95

Smartphone not included

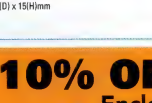
AIR VENT PHONE CRADLE WITH WIRELESS QI CHARGING HS9058

Dock your Qi supported Smartphone anytime and it will automatically charge. Universal. Easily detachable base. Works with latest phone models.

- 90(H) x 66(W) x 45(D)mm

10% OFF POWER SUPPLIES

Enclosed, Encapsulated & Din Rail



NOW FROM **$26.95**

ENCLOSED LRS SERIES

A range of compact, highly efficient, fixed voltage, no load power (0.2W–0.75W) consumption suitable for industrial automation machinery, industrial control system, electronic instruments, equipment or apparatus, household appliances.

- Withstand 300VAC surge input for 5 seconds
- Ultra compact and 1U low profile
- 5G anti-vibration capability
- Power on LED indicator

35W, 75W, 100W,150W & 320W AVAILABLE

NOW FROM **$35.95**

ENCAPSULATED IRM SERIES

A miniature encapsulated AC/DC power supplies features compact size and extremely low (<0.1W) no load power consumption at standby mode. Suitable applications include electronic instruments, hand held electronics, factory automation and electrical or mechanical equipment

- Miniature size, high power density
- Fully isolated plastic case
- Cooling by free air convection
- 5G anti-vibration capability

30W 5V & 12V AVAILABLE

NOW FROM **$35.95**

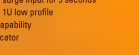
DIN RAIL HDR SERIES

Feature an ultra-slim, step shape plastic housing and low (<0.3W) no load power consumption. Typical applications include building automation, household control system, industrial control system, factory automation and electro-mechanical apparatus.

- Ultra slim design with 17.5mm(1SU) / 35mm(2SU) / 52.5mm (3SU) width
- DIN rail TS-35/7.5 or 15 mountable
- DC output voltage adjustable
- Cooling by free air convection

15W, 30W & 60W AVAILABLE

FROM **$19.95**
SAVE $5



20VA TOROIDAL TRANSFORMERS

High efficiency, small size, & low electrically induced noise . Easy single bolt mounting.

- Outer/Inner 74mm / 21 x 30mm.

9+9 VOLTS MT2082 **WAS $29.95 NOW $24.95 SAVE $5**
12+12 VOLTS MT2084 **WAS $24.95 NOW $19.95 SAVE $5**
15+15 VOLTS MT2086 **WAS $24.95 NOW $19.95 SAVE $5**

24V EI CORE TRANSFORMER MM2012

WAS $27.95
$24.95
SAVE $3

Type 215# single winding transformer with 200mm fly leads on primary and secondary connections.

- 24V, 72VA, 3A rated

ISOLATED STEPDOWN TRANSFORMERS

Fully-enclosed with fold up metal carry handles. Approved 3-wire power cord & US style 2 pin 110 - 120V socket. Electrically isolated between primary and secondary. 240V - 120V.

120W MF1080
WAS $119 NOW $99 SAVE $20
250W MF1092
WAS $169 NOW $149 SAVE $20
500W MF1094
WAS $289 NOW $259 SAVE $30
1000W MF1095
WAS $399 NOW $369 SAVE $30

FROM **$99**
SAVE UP TO $30

Selecting The Right LED Driver For Your Needs:

In efforts to conserve energy globally, Mean Well has consistently introduced new series of LED Power Supplies. Our wide range includes products which offer higher efficiency, lower power dissipation, compliance with the latest domestic and international lighting regulations.

Mean Well LED Power Supplies are ideally suited for street lighting, architectural lighting, decorative lighting, embedded lighting, indoor lighting, stage and theatre lighting and LED signage.

Their robust design and high protection levels against dust and moisture, means they can be installed in many indoor and outdoor LED applications.

MEAN WELL

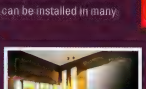
LOW POWER APV Series

- Constant Voltage / Plastic Case
- 300mm long lead

12W 12V 1A MP3371
WAS $29.95 NOW $22.95 SAVE $7
16W 12V 1.25A MP3372
WAS $38.95 NOW $29.95 SAVE $10
16W 24V 0.67A MP3373
WAS $39.95 NOW $29.95 SAVE $10

✔ 12/24V OPTION
✔ INDOOR USE
✔ IP42 RATED

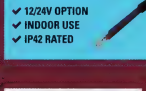
FROM $22.95
SAVE UP TO 25%


BATHROOM STRIP LIGHTS

DECORATIVE LIGHTS

KITCHEN STRIP LIGHTS

ROBE STRIP LIGHTS


PANEL LIGHTS

TUNNEL LIGHTS

SIGN LIGHTS

DOWN LIGHTS

MEDIUM POWER LPF Series

- Constant Current / Dimmable / Plastic Case
- Built-in 1.8m SAA approved input lead with AU plug

40W 12V 3.34A MP3374
WAS $79.95 NOW $62.95 SAVE $17
40W 24V 1.67A MP3375
WAS $79.95 NOW $62.95 SAVE $17
60W 12V 5A MP3376
WAS $89.95 NOW $69.95 SAVE $20
60W 24V 2.5A MP3377
WAS $89.95 NOW $69.95 SAVE $20

✔ 12/24V OPTION
✔ INDOOR OR OUTDOOR USE
✔ IP67 RATED

FROM $62.95
SAVE 20%

HIGH POWER ELG Series

- Constant Voltage & Current / Dimmable / Metal Case
- Built-in 1.8m SAA approved input lead with AU plug

60W 12V 5A MP3378
WAS $99.95 NOW $79.95 SAVE $20
75W 24V 3.15A MP3379
WAS $99.95 NOW $79.95 SAVE $20
150W 12V 10A MP3380
WAS $119 NOW $89 SAVE $30
150W 24V 6.25A MP3381
WAS $119 NOW $89 SAVE $30

✔ 12/24V OPTION
✔ INDOOR OR OUTDOOR USE
✔ IP67 RATED

FROM $79.95
SAVE UP TO 25%

FLOOD LIGHTS

SIGN LIGHTS

ARCHITECTURAL LIGHTS

STREET LIGHTS

Workbench Essentials:

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

$89

6

WAS $249
$199
SAVE $50

1. **25W 240V SOLDERING IRON** TS1465
   - Stainless steel barrel
   - Orange grip impact resistant handle
   - Fully electrically safety approved

2. **PORTABLE LABORATORY POWER SUPPLY** MP3844
   - Adjustable from 0.3V to 30V at up to 3.75A
   - 50W max. continuous power
   - Digital controls and a large display
   - Work in constant voltage and current modes

3. **DIGITAL TACHOMETER** QM1448
   - Measures up to 99,999 RPM
   - Large LCD display, laser pointer, low battery indicator, memory recall etc.
   - Supplied with carry case
   - Detection distance: 50mm to 500mm
   - 4 x AA batteries included

4. **DIGITAL VERNIER CALIPER** TD2062
   - Stainless steel. 5-digit LCD
   - 0 - 150mm (0-6") range
   - Resolution 0.01mm / 0.0005 (repeatability same)
   - Thumbscrew slide damper
   - LR-44 battery supplied

5. **CAT III INSULATION TESTER/ MULTIMETER** QM1493
   - High voltage insulation testing
   - 4000 Display count, 1000V
   - Insulation test: 40ohms @ 125 - 1000V
   - Moulded storage case and holster included

6. **5 DIOPTER LED ILLUMINATED MAGNIFYING LAMP** QM3548
   - Magnify and illuminate objects
   - Metal frame with main extension arm manoeuvrable for perfect positioning
   - Mains powered
   - 90 x bright white LEDs

WAS $39.95
$34.95
SAVE $5

WAS $79.95
$69.95
SAVE $10

WAS $199
$169
SAVE $30

$13.95

$149

0-36VDC, 0-5A SLIMLINE LAB POWER SUPPLY MP3842

Compact unit for your workbench or mobile toolkit. Provides up to 80W of power. Constant current and voltage options. Includes banana to alligator clamp leads.
- 0-16V/5A, 0-27V/3A, 0-36V/2.2A
- 53(W) x 300(D) x 138(H)mm

$12.95

BATTERY, CHARGER AND ALTERNATOR TESTER QP2258

Compact, lightweight, includes 600mm leads with croc clips, and inbuilt magnet to secure the unit while taking measurements.
- 12VDC
- 120(L) x 33(W) x 20(D)mm

$14.95

CRIMPING TOOL FOR NON - INSULATED LUGS TH1834

Handles non-insulated lugs from 14-18 AWG and 22-26 AWG. Built-in wire cutter.
- 185mm long

$14.95

SELF-POWERED LED PANEL METER QP5581

Simple 2 wire connection for voltage readout. Suitable for use between 4.5V and 30VDC. Easy to read LCD display.
- 4.5-30VDC input
- Cutout size: 45(L) x 26(W)mm

$16.95

CORDLESS VOLTAGE TESTER QP2212

Quick and easy way to locate electrical faults without a bulky meter. Works on 3-28V circuits.
- Chrome metal construction
- Probe supplied

$17.95

PANEL METER MU45 STYLE - MOVING COIL TYPE QP5016

0 - 20A. Nuts and washers supplied.
- 58(W) x 52(H)mm.
- Coil Resistance: 0.003 ohm

$19.95

12 PIECE AUDIO AND INTERIOR REMOVAL KIT TH2339

Prevent scratching and damaging your vehicle interior. Designed to suit any car model.
- 250(L) x 91(W) x 35(H)mm

$179

0 TO 30VDC 0-5A REGULATED LAB POWER SUPPLY MP3840

A must have for your laboratory or home workbenches. Features digital control, large LED display, built-in over-current & short circuit protection.
- 0-30V/0-5A
- 270(L) x 120(W) x 185(H)mm

$19.95

3-30VDC TESTER WITH VOLTAGE/ POLARITY READOUT QP2216

Provides an accurate voltage readout as well as polarity check. Works on 6/12/24V systems. Stainless steel testing probe.
- LED Indicators: Green (-), Red (+)
- Working Voltage Range: 3V-30V (±0.3V Accuracy

$22.95

LED VOLTMETER 5-30VDC QP5582

Easily monitor your vehicles battery voltage or voltage in any DC powered system. Connection is via 6.3mm spade terminals.

$23.95

AUTOMOTIVE FUSE PACK SF2142

120 standard size automotive fuses housed in a 6 compartment storage box. 20 x 5A, 10A, 15A, 20A, 25A & 30A fuses included.

EXCLUSIVE CLUB OFFERS:

FOR NERD PERKS CLUB MEMBERS

WE HAVE SPECIAL OFFERS EVERY MONTH. LOOK OUT FOR THESE TICKETS IN-STORE!
NOT A MEMBER? Visit www.jaycar.co.au/nerdperks

NERD PERKS CLUB OFFER

2 FOR $30

4-WAY POWERBOARD
WITH 3M LEAD
MS4053 **REG $19.95 EA**

SAVE 20%

NERD PERKS CLUB OFFER

ONLY $59.95

4 DOOR REMOTE CONTROLLED CENTRAL LOCKING KIT
LR8842 **REG $89.95**
Lock and Unlock your car doors from a distance.

SAVE $30

NERD PERKS CLUB OFFER

ONLY $119

LED HEADLAMP KIT SL3524 **REG $169**
- H4 Hi/Lo
- 3800 Lumens 40W

SAVE $50

NERD PERKS **SAVE 15%**

DESKTOP STYLE POWER SUPPLY
MP3241 **REG $84.95 CLUB $69.95**
120W 12VDC 10A Switchmode.

NERD PERKS **SAVE 20%**

SPEAKER CABLE - 30M ROLL
WB1703 **REG $12.95 CLUB $9.95**
2-core 24AWG figure 8. Light duty.

NERD PERKS **SAVE 25%**

PROGRAMMABLE INTERVAL 12V TIMER MODULE AA0378 **REG $39.95 CLUB $29.95**
12VDC. 72(L) x 65(W) x 43(H)mm.

NERD PERKS **SAVE 25%**

ILLUMINATED GOOSENECK MAGNIFIER
QM3532 **REG $29.95 CLUB $21.95**
Flexible metal arm.

NERD PERKS **SAVE 20%**

U16 FERRITE VOLTAGE SPIKE PROTECTORS/ NOISE SUPPRESSORS - PK 4
LF1292 **REG $12.95 CLUB $9.95**

NERD PERKS **SAVE 20%**

100 PIECE DRIVER BIT SET TD2038 **REG $24.95 CLUB $19.95**
Includes magnetic holder, Phillips bits, slotted bits, torx, etc.

NERD PERKS **SAVE 25%**

LARGE ABS IP66 ENCLOSURES
HB6412 **REG $34.95 CLUB $24.95**
175(L) x 125(D) x 75(H)mm.

NERD PERKS **SAVE 30%**

BUTYL BASED SOUND DEADENING MATERIAL AX3687 **REG $29.95 CLUB $19.95**
900 x 330mm. 1.5mm thickness.

NERD PERKS **HALF PRICE**

COAX SEAL TAPE
NM2828 **REG $12.95 CLUB $6.45**
12mm wide x 1.5m long.

NERD PERKS **SAVE 25%**

POCKET MOISTURE METER QP2310
REG $34.95 CLUB $24.95
Auto power off. Backlit digital LCD screen.

NERD PERKS **SAVE 35%**

LED PACK ZD1692
REG $13.95 CLUB $8.95
5-20mcd @ 20mA. Packet of 100. Red.

NERD PERKS **SAVE 30%**

160RPM 12VDC REVERSIBLE GEARHEAD MOTOR
YG2738 **REG $43.95 CLUB $29.95**
50kg.cm torque at 50RPM.

NERD PERKS CLUB MEMBERS RECEIVE:

10% OFF*

12V IN-CAR POWER SUPPLIES

*Applies to Jaycar 40SA: 12V Power Supplies (Car)

YOUR CLUB, YOUR PERKS:
CHECK YOUR POINTS & UPDATE DETAILS ONLINE.
LOGIN & CLICK "MY ACCOUNT"
Conditions apply. See website for T&Cs.

NEW 2018

What's New:

We've hand picked just some of our latest new products. Enjoy!

TECH TALK:

Redundant Array of Independent Disks (RAID)

RAID is a way of storing the same data in different places on multiple hard disks to protect data in the case of a drive failure.

USB 3.0, 2 BAY Raid HDD Enclosure XC4688

Have your files backed up. Tool less & driverless. Supports 2.5" and 3.5" HDD

- Raid 0, Raid 1, JBOD
- Backwards compatible with USB 2.0
- Capacity: 8TB Per Bay
- 135 x 215 x 115mm

Due Early November.

$169

$14.95

Due Early November.

UNIVERSAL 4 CHANNEL NI-MH BATTERY CHARGER MB3557

Individually monitored channels with LEDs for quick-glance charging status. USB powered. Suitable for AA and AAA Ni-MH batteries. Ultra portable.

$99.95

MONITOR STAND WITH USB HUB AND CARD READER XC4312

Low Profile. 3 x USB 3.0 Ports. 1 x USB 3.0 Quick Charge Port. SD / Micro SD Card Reader.

- Input: USB3.0
- 555 x 200 x 55mm

Due Early November.

XC4687

FROM $44.95

USB 3.0 SATA HDD DOCKING STATIONS

Connect 2.5" or 3.5" SATA hard drives to your computer. *Due Early November.*

- Transfer Rate: 430Mbps
- HDD capacity: 8TB

SINGLE DOCK XC4687 **$44.95**

DUAL DOCK XC4689 **$59.95**

$19.95

IN-CAR CHARGER FOR DASH CAMERA AND GPS NAVIGATION MP3883

Convenient power for dash cameras and GPS units. Works in cars or trucks with a voltage range of 10-30V. 2.4A USB charging port.

- Mini-USB 3m charging cable
- Cigarette lighter connection

$19.95

DUAL USB WALL CHARGER WITH LED NIGHT LIGHT MP3429

Compact, light weight, multi-functional dual USB wall charger with LED night light. Multiple light modes.

FROM $39.95

Due Early November.

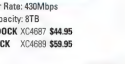
GIGABIT ETHERNET SWITCHES

Easily create or expand your wired network. Plug and play.

- 10/100/1000 Mbps Ethernet Ports
- 10Gbps Backplane Bandwidth

5 PORT YN8384 **$39.95**

8 PORT YN8386 **$59.95**



$39.95

USB 3.0 ETHERNET CONVERTER

YN8418

Provides a solution by converting a USB port to an ethernet port.

- Network connection: RJ45, 10/100/1000

Due Early November.

Motorized Robotic Arm Kit

STEM BASED CONSTRUCTION KIT WITH OVER 350 VEX® SNAP TOGETHER ROBOTICS PIECES KJ8995

Ages 8+.

- Can pick up and relocate items
- Crane can rotate 360 degrees
- Includes two alternate builds
- Articulated grabber hand

$139

STEM

TERMS AND CONDITIONS: REWARDS / NERD PERKS CARD HOLDERS FREE GIFT, % SAVING DEALS, DOUBLE POINTS & MEMBERS OFFERS requires ACTIVE Jaycar Rewards / Nerd Perks Card membership at time of purchase. Refer to website for Rewards/ Nerd Perks Card T&Cs. PAGE 3: Nerd Perks Card Holders receive a special price of $84.95 for GPS Speedometer project kit when purchased as bundle (1 x XC4420 + 1 x XC2712 + 1 x XC4633). PAGE 4: 10% OFF Power Supplies applies to Enclosed UPS Series (50W, 75W, 100W, 150W & 320W), Encapsulated IRM Series (30W SV & 12V) & DIN Rail HDR Series (15W, 30W & 60W). PAGE 7: Nerd Perks Card holders receive Special discount on 4 Door Remote Controlled Central Locking Kit (LS8842) for $59.95 & and LED Headlamp Kit (LL3534) for $11.8. Nerd Perks Card Holder Offer: Buy 2 x Powerboards (MS4050) for $30. Nerd Perks Card Holders receives 10% OFF 12V In-Car Power Supplies: Applies to Jaycar 40BA: 12V Power Supplies (Car).

NEW STORE: AUBURN

233-239 Parramatta Rd, NSW 2142

PH: 1800 022 888

FOR YOUR NEAREST STORE & OPENING HOURS:

1800 022 888

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SERVICEMAN'S LOG

It's torture having a broken phone

Dave Thompson*

It isn't often one gets to be on the other side of the servicing coin. These days, most of the time when something goes wrong, I can sort it out with the deft turn of a screwdriver or a quick touch with the soldering iron. But when you don't have any tools handy, it's a bit hard to fix something, even if you're the world's best serviceman.

Items Covered This Month

- A broken phone and a serviceman without tools
- R&S CRO repair

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If you've been following my travails in this column, you will know that I was recently staying in the Dalmatian coast of Croatia. Since then, I've driven to Munich, in Germany. The trip was very straightforward, as the well-signed highway system is designed to carry vast amounts of traffic.

I loved the high-but-safe cruising speeds, the exotic cars on display in their natural habitat and the ease of navigating through three different countries to get where we were going. I marvelled at the vast wind farms and massive solar arrays that dotted the landscape, especially through the Austrian Alps and the Bavarian countryside.

Every farmhouse we saw had almost the entire roof covered with panels, and we guessed that during winter, when the snow was deep and power supply dodgy, that they would very much come in handy.

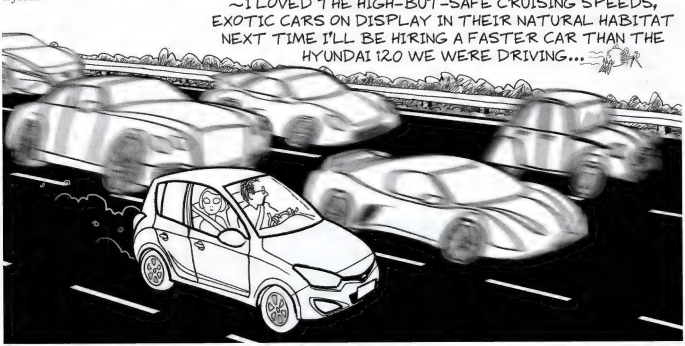
I didn't get to see the back end of these systems, so I do not know how energy was stored or the panel output processed, but whatever was used, it was very prevalent.

We also saw fields that would otherwise be sewn with wheat or hops covered instead with solar arrays, set up to track the Sun's path across the sky. In some spots, all we could see were these solar fields and this is alternative energy on an industrial scale, a bit like the tourist industry itself in Germany.

Welcome to Germany, please open your wallet

On the face of it, everything there is designed to extract money from the visitor. Want to park somewhere? That costs money – even hotels and motels charge for precious parking spaces. Need a toilet break during your visit to any of the town-sized shopping malls? Better have some small change in your wallet, or you'll be holding it in.

I got the impression that if they could charge for the amount of air you breathed, they would. That aside, it is



a beautiful place and this trip ticked off a few of my bucket-list entries, so all was forgiven.

Next time (if there is one), I'll be hiring a faster car than the Hyundai i20 we were driving. Then again, it's well known that there is no faster car than a rental car. But as this was a brand-new car when we picked it up, it hadn't been thrashed to within an inch of its life yet. We did around 7000km in it in the past four weeks so I'd say it is probably run-in by now!

However, the trip was not without its dramas, which brings me to my point (as usual, a while coming). Shortly before we left on our Deutschland sojourn, my wife and I treated ourselves to a new mobile phone each, taking advantage of the sharp pricing available in Croatian stores.

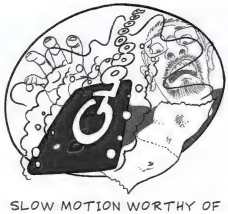
We both got a 2018 Samsung J6, a smaller phone than the Lenovo I was replacing but with a far better OLED screen, an octa-core CPU and 32 gigs of storage. They also take two SIMs, one of my buying prerequisites; having a work number and a private number in the same phone makes things a lot easier. I liked it, and from day one was snapping photos with its excellent 13-megapixel camera.

I'd bought a local SIM, which would roam all over the EU without invoking the crippling charges our Antipodean telcos seem to relish in gouging from overseas travellers. It's great; travel from, say, Slovenia to Austria and literally as you go through the border, a text message informs you that you are now connected to an Austrian provider and that charges and rates will be the same as they were in your home country.

Time to spend a penny

So I was loving this phone. The first day in Germany, we checked into a hotel in central Munich and after wandering about the town and shopping, I went into the bathroom to wash up. My phone was in my pocket, and given the tiny size of the bathroom, it was in the way. So I put it on the glass shelf above the sink.

As I washed my hands, I saw out of the corner of my eye my phone, in the sort of slow motion worthy of an action movie sequence involving the protagonist leaping away from an explosion, sliding along and off the now obviously forward-sloping shelf and straight into – you guessed it – the toilet bowl.



SLOW MOTION WORTHY OF AN ACTION MOVIE SEQUENCE

With a sickening gloop and porcelain thunk, it sank into the (thankfully) clean bog water and immediately came alive, only to go dark a brief second later. Nooooooooooooooooooooooooooooo! My new phone! Only weeks in my possession! Down the toilet!

I could only curse my imbecility. Panicking, I fished the phone out and tried to power it down, only for it to appear dead/non-responsive. It had only been in the water for a matter of seconds but the damage was done.

About now is where I stretch the bounds of reader's credibility; that very morning whilst shopping, we'd found an Asian foods store, something very rare in our part of Dalmatia. We bought, among many other things to create eastern-inspired meals for the family, a one-kilo bag of Jasmine-scented basmati rice. You couldn't make this stuff up.

Desperate times call for desperate measures

While I soaked as much moisture from the outside of the phone as I could with a copious number of tissues, my wife located the bag of rice and tore it open. She also found an old zip-lock bag among our stuff, so I put the phone inside and filled it up with rice.

I evacuated most of the air and zipped the bag up. The drama over for the moment, I could only rue the decision to put the phone on that glass shelf. I also resolved that whatever phone I ended up with next, I'd buy a proper protective case for it at the first opportunity.

Not that this would prevent stupidity on my part, or even water-proof the phone, but it does seem awfully vulnerable in its naked state. While I've seen phones with cracked screens that had been in decent cases, at the very least, it would give me some peace of mind.

The phone sat sealed in that bag of rice for the next three days, while I relied on my wife to take photos on her phone that I would have liked to save. On the morning of the fourth day, I carefully removed the phone and extracted the SIMs from it (my original and the new local SIM) and the 16GB SD card I'd transferred from my old phone.

On reflection, I probably should have removed them right away but two things prevented me from doing this; firstly, all I could think about was getting the phone into the rice and secondly, this phone has a sealed back and the SIMs and SD card are seated in small plastic trays before being slipped into the side of the phone.

To remove them, you need one of those pointy tools or a bent paper clip, neither of which I had on hand at the time. Once the phone was in the rice, I didn't want to be removing it unnecessarily.

I didn't know if this rice pack would work; I'd read about it online and had seen it mentioned on police procedural TV shows. I'd even heard of clients trying it but for the life of me, I couldn't recall whether their outcomes were successful or not.

Even if it's only an urban myth, it does make sense; I suppose a bag full of the silica gel bags you get packed with everything these days would work even better but a grain of rice does have the ability to soak up a huge amount of moisture, relative to its size, so perhaps this would achieve something.

It's dead, Dave

But as I removed the SIMs and memory card from the phone, I could see the display showing half the charging

Servicing Stories Wanted

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Please be sure to include your full name and address details.

symbol and the LED flickered dimly away all by itself, telling me the phone was not happy. I, of course, tried pressing the buttons with the same underwhelming result as before; I thought the phone must have had it.

Nonetheless, with great faith, I placed the phone back into the bag of rice and put it in my suitcase. There it would stay until I got back to Dalmatia and could look into repairing it.

Not having the SIM popper tool was bad enough; not having any tools whatsoever with which to disassemble the phone was a form of torture. I knew if I could get into it and physically separate and dry the parts, I'd have a much better shot of getting it to work again. But getting into phones is tricky at the best of times, and I was sans tools and workshop.

I know what you're thinking; I could have found some German repair guy to open it up for me but given how expensive we found Germany, it likely wouldn't be worth it. I recommend that clients in the same position as me make an insurance claim, as the device is likely going to have a significantly shortened lifespan even if you do manage to resurrect it.

When we got back to Croatia, I put the bag out into the sun, just to sweat any further moisture from the phone. Temperatures in Germany were about half those in Croatia, with some rainy days involved, so the rice bag didn't get very warm; maybe this would help. While it baked in the sun, I looked for a YouTube teardown video for this model phone.

I couldn't see any way to get into it except through the screen, like an iPhone, and my suspicions were confirmed by the video I found. I'd need a heat gun at the very least, and some very thin spudgers to disassemble it. Plus, I didn't have my screwdrivers or usual workshop facilities either, a recipe for disaster given the number of screws and small bits inside the phone. Opening it up myself simply wasn't an option.

A serviceman hates to give up

And so for a few days, we did nothing about the phone, and when I finally removed it to test it, it was still dead. It wouldn't power up or display anything at all and when connected to my laptop, it showed no signs of charging. Nor did the laptop recognise there was anything attached. Excellent.

There was nothing for it but to go and buy another phone and relegate this one to the scrap heap and a possible insurance claim once we got back to New Zealand. It left a bitter taste going to the same store and buying an identical phone mere weeks after buying the last one, but it had to be done.

With the new phone suitably bought and configured to my liking – a story in itself – I found the SD card from the "toilet phone" was no longer working properly. It randomly dropped in and out of the system, causing alerts and notifications. While it was working, I spent ages copying the 15 or so gigabytes of magazines, saved photos and other data from it to the new phone's internal storage.

A few days after this, my Croatian brother-in-law came by for a visit and said he knew of a local guy who repaired phones and didn't charge the world, so I went to grab my toilet phone. After getting it out of the rice bag, I tried the power button, just to see what would happen.

The Samsung logo flashed onto the screen and the boot process began. It seemed to be working! I had no SIMs or memory card installed but the phone booted into emergency call mode and a quick check showed everything was operational.

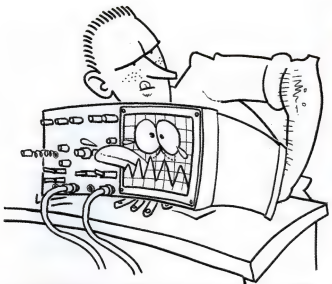
Still suspicious, I took it over to my laptop and connected it, firstly because it only had a 5% battery charge left and secondly because I wanted to get the data off it while it was alive. And I did manage to grab all the photos and videos I'd taken in the few weeks I'd had it – which was a huge relief.

My brother-in-law rang up the aforementioned repair guy and asked what he would do. He suggested leaving it for the moment, since removing the screen to access the logic boards has its own risks. He felt that (toilet) water was far less caustic than other liquids he often finds inside phones, such as beer or cola, so it might have actually escaped any lasting damage.

I agreed with his suggestions. Great! Now I have two identical phones.

I left the toilet phone connected to the computer until it had charged to 100% and stuck it back into the bag of rice. It can stay there for now, until I'm convinced every drop of moisture is gone.

I'm reasonably certain it will live a normal life but I can't really sell it on in good conscience, so I will hang



onto it for spares, just in case – God forbid – I drop this new one, or otherwise ruin it.

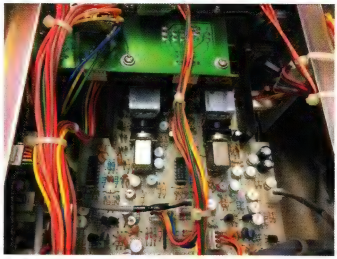
Rohde & Schwarz CRO repair

M. H., of Albury, NSW, found a dual-trace cathode-ray oscilloscope that someone else had thrown away in a skip bin. While an accountant would immediately determine the cost of repair to be far beyond its potential value, he decided to try to repair it anyway...

It was a fairly late model Rohde & Schwarz cathode-ray tube scope with the top and bottom covers already removed, presumably because someone had a go at fixing it before giving up and chucking it out.

A few blasts of compressed air removed the dirt and dust and then I took it to my workshop to try to figure out what was wrong. I rudely powered it up and jammed a 1kHz test tone into both inputs in an attempt to get a trace. Nothing appeared but I didn't know whether it was because I simply didn't know how to operate this unit. Maybe it was actually dead.

After five minutes, eventually two traces appeared. Surprised, I continued to test some of its other functions. I found that the gain of one channel was way off. By comparing the inputs with my trusted Trio oscilloscope, the gain calibration of the faulty channel proved to be good until the volts per division knob was above 1mV/div and it was wrong on all of the higher settings.



The inside of the CRO shows multiple different trimpots scattered over one of the boards.

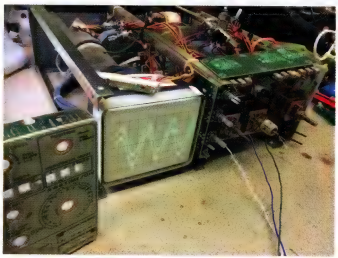
I wasn't sure if it was a fault or it simply needed adjustment but with dozens of adjustable resistors and capacitors scattered everywhere on the PCB, I wasn't convinced that I could figure out how to adjust it even if that's all that was wrong with it. Oh dear.

For any technician, sighting an adjustable pot or variable capacitor means one must immediately twiddle. If one cannot resist then at least one must immediately return any adjustment back to the original position. In this case, it was wise to resist. I had no circuit diagram or any hint of what each one did and the box was full of them. Twiddle time finished with no result.

The next job was to remove the front panel to allow access to the cluster at the front where the fault was likely to be located.

After removing many knobs, switches, retaining nuts and screws, the front was finally off but the fault had disappeared. Both traces were now correct and I could not reproduce the problem. So I switched it off and walked away.

On first power up, the traces settled after a long wait and calibration was OK but only on the lower volt/div settings.



Mid operation: the offending variable cap is just behind the first plate of the switch with the knob still attached.

Next morning, I powered it up but after two minutes, there was still no trace. After an extended delay, I observed a faint hint of a trace on the top outer edge of the screen that would not be visible if the front panel was attached.

The expected traces ever so slowly lowered themselves down onto the screen and eventually moved down to the (almost) correct position. But the fault in the one trace had returned.

At this stage I was pretty sure that both the lack of traces initially and the incorrect position of the one trace were heat-related faults.

With an SMD rework heat gun set on the lowest fan setting and with a fine nozzle, I applied heat onto a single adjustable capacitor, selected at random and close to the input connection. The faulty trace jumped instantly. Inspection of the underside of the PCB traces did not identify any dry joints on that component.

I had to use a metal blade screwdriver to break the variable capacitor adjustment free and then I was able to use a plastic blade for the final adjustment. The first movements of the variable capacitor caused the trace to jump wildly. I exercised the variable capacitor back and forth until its actions on the trace become clean and linear.

The driver circuit that allows adjustment of the traces up and down is located at the end of the delay line, which is a long cable coiled up in the bottom of the case.

A few tweaks was all that was required to adjust the centre line correctly and this also included another variable capacitor that I needed to break free, like the last one.

I then applied a frequency sweep from 100Hz to 4MHz and adjusted other variable caps at the front end to try to get a flat response.

Eventually it looked good and the volts/div setting was now having the correct effect on both traces. So that I could check its power-on behaviour, I switched it off and walked away.

After an hour or so, I switched it back on and the traces were immediately in the correct position. I heated the components at the end of delay line with no changes. I then heated the components at the start of the delay line and both traces moved in different directions as the board warmed up.

I then decided to applied freeze spray to the components near the start of the delay line, using a tube to funnel it down to a single component at a time. Cooling any of the components had some effect on the trace. I concluded that this heat/cold sensitivity was normal and not likely to be a problem during normal operation.

So I guess both problems were due to the variable capacitors all along. Exercising them may have been breaking away internal corrosion that was interfering with proper operation.

The next hour was spent getting the covers back on. The scope was now working well enough considering its age. To verify this, I waited until the next morning and powered it up to find both traces in the correct position after a short warm-up period.

Given how long I spent fixing it and considering how much I would have had to pay someone else to do the job, I could have easily bought a new digital scope instead. But electronics is my hobby and I enjoyed fixing it so I think it was well worthwhile. SC

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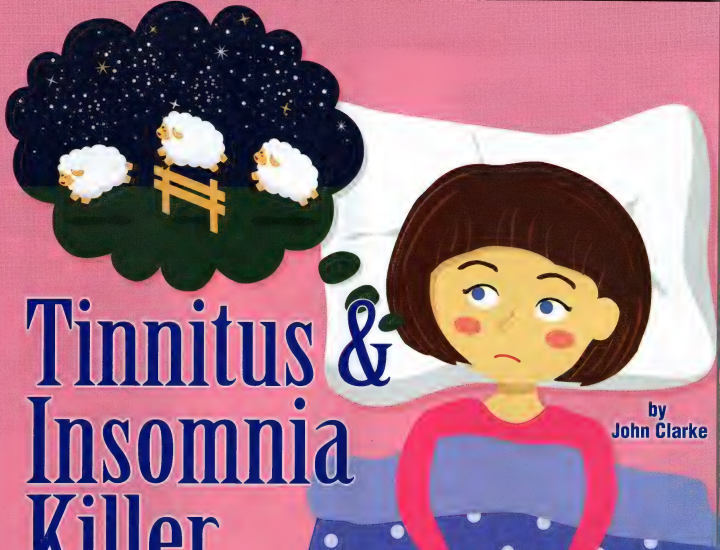


Tinnitus & Insomnia Killer

by John Clarke

Do you – or someone you know – suffer from Tinnitus? How about Insomnia? We can't make any therapeutic promises but pink and/or white noise is widely recognised as easing or even eliminating those problems! This device produces either pink or white noise so you can experiment to your ears' content – and maybe get some relief!

If you have never suffered from Tinnitus, consider yourself fortunate! Tinnitus is the perception of sound when no external sound is present.

Commonly referred to as "ringing in the ears", Tinnitus may sound like humming, clicking, buzzing, ringing, hissing, roaring, whistling or even the sound of crickets.

It's especially maddening for those who suffer from it constantly. Tinnitus may be intermittent or constant and may vary in loudness depending on stress, blood pressure, tiredness, medications and the surrounding environment.

Some people who experience Tinnitus are not really bothered by it. But others find that it seriously disturbs their sleep. In the worst case, it can be debilitating.

For those people who are severely affected, Tinnitus Retraining Therapy (TRT) can provide an effective treatment. Developed by Dr Jawel Jastreboff, TRT involves the use of low-level broadband noise. TRT does not cure Tinnitus but it does make it manageable for people who are severely affected.

If you want to know more, there are many websites devoted to Tinnitus. Just call up "Tinnitus" in your favourite search engine and you will find lots of information.

Even if you don't suffer from this affliction, there are times when a low-level noise source can be really helpful

in masking extraneous noise – such as when you can't get to sleep and lie there tossing and turning, getting even more worked up and even less likely to find that elusive sleep!

Insomnia

Perhaps a nearby neighbour is having a boisterous pool party and counting sheep or hiding your head under your pillow simply doesn't work!

Switch on the Tinnitus and Insomnia Killer and you can effectively blank out the noise that's keeping you awake.

Or maybe you are trying to study and someone else in the family has swapped their ballet shoes for hob-nail boots.

Again, switch on this unit and mask it. Our only warning is that if you're trying to study, you may instead fall asleep. Oh well, can't win 'em all!

How does it do this?

The Tinnitus and Insomnia Killer masks external sounds by increasing the ambient noise level so that the unwanted noise is much less obtrusive.

The "noise" from this unit is something you can live with – in fact, it is often quite soothing. It has been likened to what you hear from light rain on a tin roof, a soft waterfall or a stream cascading down rocks.

Babies experience constant noise like this in the womb, which is why "shushing" them often calms them down and helps them get to sleep.

We're all accustomed to this sort of noise when we are very young. So it can be especially effective at helping babies to sleep, even when they are in a quiet environment. To them, a quiet environment is quite an alien concept!

Finally, another use for white/pink noise: relaxation. There might be no doof-doof noise from the neighbour's party – in fact, it might be too quiet for you to relax. Just add a little noise (of the right type!) and you'll probably find you can relax much easier. . .

All-new 2018 design

The Tinnitus and Insomnia Killer can drive headphones or a loudspeaker. And it can be powered from a 9V battery or a DC plugpack (from about 6-12V).

It's built into a small plastic case and it includes a volume control to set the level that suits YOU!

By the way, we published a similar Tinnitus and Insomnia Killer in the September 2001 issue. We still get enquiries about that project.

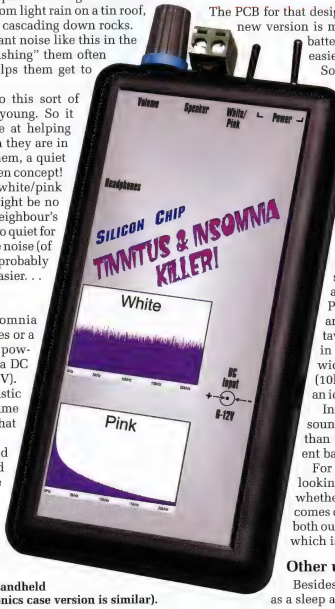
However, the PCB for that design is no longer available and this new version is much more portable, has a longer battery life, more output power and is easier to build.

So the 2001 version can now be considered truly obsolete.

Features and Specifications

- Produces white or pink noise
- Onboard volume control
- Drives headphones, earbuds or a loudspeaker (up to 750mW into 8Ω)
- Powered from a 9V battery or 6-12V DC plugpack
- Power-on and low battery indicator
- Small and light portable (handheld) unit
- Current draw with headphones: 4.6mA quiescent, 8-9mA# at medium volume, 20-25mA# at full volume
- Current draw with speaker: 8.6mA quiescent, 47-80mA# at full volume
- 9V battery life: typically around 48 hours with headphones or 7 hours with speaker

 # lower figure is for white noise, slightly higher for pink noise



The Tinnitus & Insomnia Killer, housed in a Jaycar handheld instrument case. (The Altronics case version is similar).

White noise, pink noise: what's the difference?

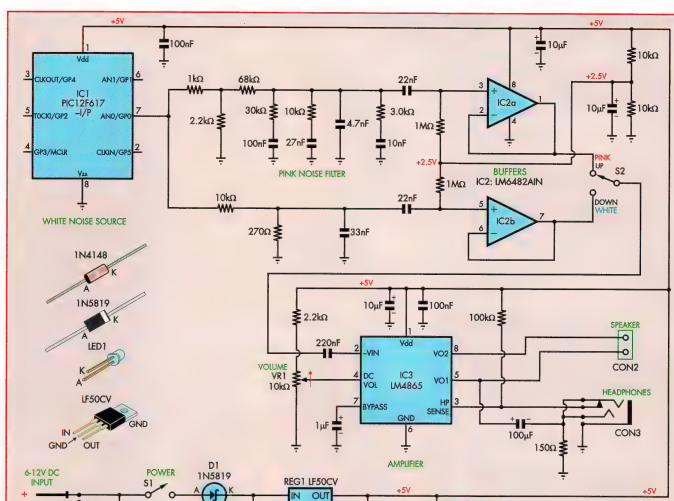
White noise has equal energy at all frequencies across its entire bandwidth. So for example, the 1kHz band from 1-2kHz will have the same total energy as the 1kHz band from 10-11kHz. In practice, this means that white noise has a 3dB rise in amplitude for each higher octave. It sounds similar to steam escaping or when an FM radio is tuned off-station. Pink noise, on the other hand, has an equal energy level for each octave. So for example, the total energy in the 20-40Hz band (ie, 20Hz bandwidth) is the same as from 10-20kHz (10kHz bandwidth). Therefore, it has an identical amplitude for each octave.

In effect, this means that pink noise sounds more subdued and less harsh than white noise and has more apparent bass.

For Tinnitus suffers or those simply looking to mask out unwanted noise, whether you use white or pink noise comes down to your preference. Try them both out and see which one you prefer and which is more effective in your situation.

Other uses for pink noise

Besides helping those with Tinnitus or as a sleep aid, pink noise is often used in the



SC 02/2018 TINNITUS & INSOMNIA KILLER

Fig.1: the circuit for the Tinnitus and Insomnia Killer. White noise is produced by IC1 at its pin 7 output. It is attenuated and buffered by op amp IC2b and then fed to IC3, when switch S2 is in the down position. The white noise is also converted to pink noise and buffered by IC2a and this is instead fed to IC3 if S2 is in the up position. IC3 amplifies the chosen signal and feeds it either to headphones at CON2 if nothing is plugged into CON3.

laboratory – for measuring and testing loudspeaker systems, for example.

It can be used when positioning and adjusting speakers to compensate for sound "colouration" due to objects in the room and the shape of the room. It may also be used as a guide to get consistent sound throughout a room.

The pink noise is used as a signal source to drive the loudspeaker(s) via an amplifier. The resulting sound is monitored using a calibrated microphone, ie, one with a flat response, or a known response that can be compensated for.

The microphone drives a spectrum/frequency analyser to show how the sound changes as the microphone is moved around the room.

For room equalisation, an equaliser can be used to adjust the levels in each frequency band so that the overall frequency response is flat. Our 10-band Graphic Equaliser design from the June and July 2017 issues would be a good choice (see **siliconchip.com.au/Series/313**).

However, you don't need an expensive spectrum analyser for this job as there are many computer software-based options to display the audio spectrum from a microphone.

For example, there is a program called Wavespectra (**http://nice.kaze.com/av/wavespectra.html**). Another you might be familiar with is Audacity (**www.audacityteam.org/**). There are many others: Dr Google is your friend!

Circuit description

Refer now to the circuit diagram (Fig.1, above). IC1 is a PIC12F617 microcontroller which is programmed to produce white noise using a 31-bit pseudo-random noise sequence implemented in its software.

It's called pseudo-random because it's not truly random – the sequence repeats after about eight hours. So the repetition is not noticeable nor even statistically relevant in 99.9%

Here's how the PCB fits inside the case (in this instance it's the Jaycar case; the Altronics version actually mounts to the lid).

of cases.

IC1's output signal passes to two different filters, one of which converts the white noise to pink (via IC2a) and one of which merely conditions the white noise further (via IC2b). Switch S2 determines which of these two signals is fed to amplifier IC3, allowing you to choose white or pink noise.

The internal 8MHz oscillator of the PIC12F617 is used, which gives a 2MHz instruction rate, so the 13 instructions in the software results in a sampling rate of 153.846kHz (2MHz÷13). The noise frequency distribution is therefore up to about half that, ie, 76.923kHz.

Because the output is a square wave, it will have harmonic components at higher frequencies than 76.923kHz but they will have a decreased amplitude and power level. The measured spectrum from IC1 is shown in Fig.4.

It extends over the entire audio spectrum (20Hz-20kHz) and well beyond at both the low-frequency and high-frequency ends.

Compare this to the spectrum of the pink noise produced by this unit, shown in Fig.2, to that of the white noise, shown in Fig.4 This is different to that shown in Fig.2 because of the extra filtering and attenuation in the analog signal path. Most of the supersonic and subsonic frequencies are filtered out.

For more information on how IC1 produces white noise, see the White Noise Generator article published in the September 2018 issue (siliconchip.com.au/Article/11225).

Filters

The white noise from IC1 is reduced in level using a resistive divider comprising 10kΩ and 270Ω resistors. This is so that the white noise is at a similar level to the pink noise, so that switching between the two will not cause a noticeable jump in perceived volume. The supersonic (above 20kHz) signal components are then

Fig.2: the yellow trace shows the white noise output at pin 7 of IC1 with a spectrum analysis below, showing the distribution of energy across various frequencies from a few hertz up to 10kHz. As you can see, its frequency distribution is effectively flat.

Fig.3: now the yellow trace shows the pink noise output at pin 1 of IC2a and the spectrum analysis below. We've "zoomed in" to the 0-10kHz frequency range so you can see how the intensity falls off with increasing frequency in a logarithmic manner.

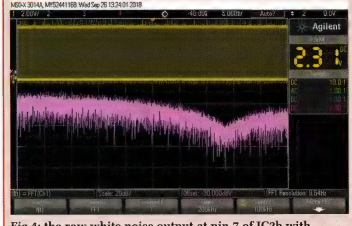


Fig.4: the raw white noise output at pin 7 of IC2b with spectrum analysis for 0-200kHz. Its amplitude is quite flat up to about 50kHz, rolling off to around -15dB at about 150kHz before increasing again, due to the harmonic content.

filtered out by a low-pass filter which consists of these two resistors plus a 33nF capacitor. The signal is then AC-coupled to non-inverting input pin 5 of buffer IC2b via a 22nF capacitor. This input pin is DC biased to half supply (around 2.5V) via the 1MΩ resistor, which connects to the junction of a voltage divider consisting of two 10kΩ resistors across the 5V supply. This half supply rail is decoupled to ground with a 10µF capacitor, so that supply noise is not injected into the signal via this path.

This DC biasing arrangement allows IC2b to produce a symmetrical swing within the 5V supply rail and thus the amplifier output will not clip.

Pink noise filter

In the other signal path, the white noise signal becomes pink noise. It is first reduced in level by the 1kΩ and 2.2kΩ resistors. This reduction is not as great as that of the white noise signal path because the following filter also provides some attenuation.

The initial attenuation from these two resistors prevents clipping in the following buffer stage (IC2a).

The pink noise filter provides a -3dB per octave roll-off. That roll-off rate is difficult to achieve because an RC filter using a resistor and capacitor provides a higher roll-off rate, of 6dB per octave.

To get the -3dB per octave roll-off, a complex network of passive step filters is used. These combine to provide an overall response with the required roll-off rate.

This filter is based on one first published more than forty years ago in the National Semiconductor Audio Handbook, 1976 (see page 2-56 of siliconchip.com.au/link/aals).

This filter is accurate to within ±0.25dB from 10Hz to 40kHz when close-tolerance components are used. The resulting signal is AC-coupled via a 22nF capacitor to the non-inverting input of buffer IC2a and biased with a 1MΩ resistor using the same arrangement as for IC2b.

The selected signal (ie, white or pink noise) at the common terminal of switch S2 is applied to the input of an LM4865 audio amplifier (IC3) via a 220nF AC-coupling capacitor.

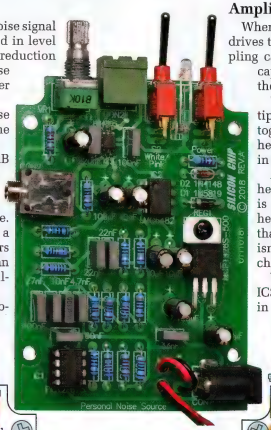
Amplifier operation

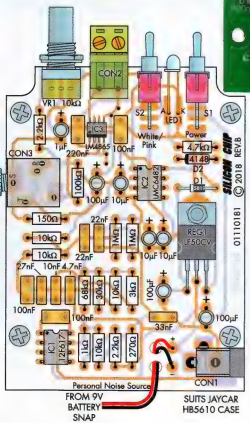
When headphones are connected, IC3 drives them via a 100µF electrolytic coupling capacitor from output pin 5. The capacitor removes any DC bias from the amplifier's output.

The headphone socket (CON3) tip and ring connections are joined together so that both sides of the headphones/earphones are driven in parallel.

A 150Ω resistor ensures that the headphone side of this capacitor is DC-biased to ground even if the headphones are not plugged in, so that when they are plugged in, there isn't a loud thump as the capacitor charges.

When headphones are not used, IC3 will instead drive a loudspeaker in a bridge-tied-load (BTL) arrange-





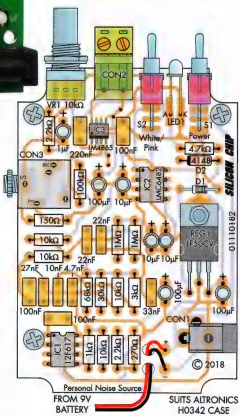


Fig.5 (left): use this PCB overlay diagram as a guide when building the board that fits into the Jaycar case. Be careful with the polarity of D1, D2, ICs1-3 and the electrolytic capacitors. Make sure that these capacitors are sitting low on the board before soldering the leads or else they may not fit in the case.

Fig.6 (right): the PCB overlay diagram for the board that fits into the Altronics case, which is slightly narrower and has different mounting hole locations. The component arrangement and interconnections are otherwise identical. Be sure to do up REG1's screw before soldering its leads to prevent damage.

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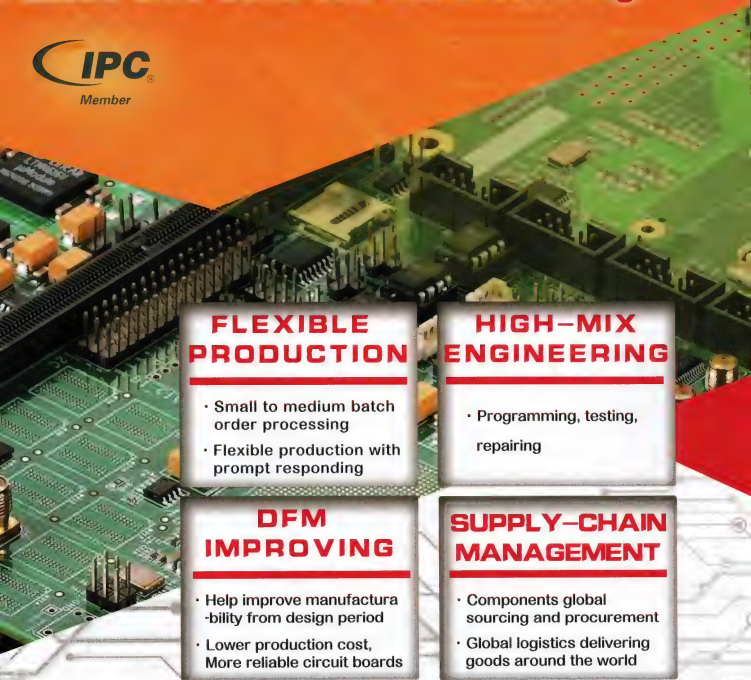

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Parts list – Tinnitus/Insomnia Killer

1 double-sided PCB coded 01110181 (63.5mm x 86mm) [to suit Jaycar case] ***or***
1 double-sided PCB coded 01110182 (58.5 x 86mm) [to suit Altronics case]
1 remote control case, 135 x 70 x 24mm [Jaycar HB5610]
or
1 remote control case, 130 x 68 x 25mm [Altronics H0342]
and
1 remote control belt clip [Altronics H0349] (optional)
1 front panel label, to suit case
1 8-pin DIL socket (for IC1)
2 SPDT PCB-mount toggle switches [Altronics S1421]
1 9V battery and battery snap
1 2.1mm or 2.5mm ID switched DC socket (CON1) [Jaycar PS0519, Altronics P0620 or P0621A]
1 2-way right-angle pluggable terminal block socket (CON2) [Altronics P2592, Jaycar HM3102]
1 2-way pluggable screw terminal block (CON2) [Altronics P2512, Jaycar HM3122]
1 3.5mm PCB-mount stereo jack socket (CON2) [Jaycar PS0133, Altronics P0092]
1 M3 x 6mm screw and M3 hex nut (for mounting REG1)
4 No.4 self-tapping screws (for Jaycar case only)
1 knob to suit VR1

Semiconductors

1 PIC12F617-I/P microcontroller programmed with 0111018A.HEX (IC1)
1 LMC6482AIN dual rail-to-rail op amp (IC2)
1 LM4865M audio power amplifier, SOIC-8 (IC3)
1 LF50CV low dropout, low quiescent current 5V regulator (REG1) [element14 Cat 1094240]
1 3mm blue LED (LED1)
1 1N5819 1A schottky diode (D1)
1 1N4148 signal diode (D2)

Capacitors

3 100µF 16V PC electrolytic
3 10µF 16V PC electrolytic
1 1µF 16V PC electrolytic
1 220nF MKT polyester
3 100nF MKT polyester
1 33nF MKT polyester
1 27nF MKT polyester (***or*** 22nF and 4.7nF in parallel)
2 22nF MKT polyester
1 10nF MKT polyester
1 4.7nF MKT polyester

Resistors (all 0.25W, 1% metal film)

2 1MΩ 1 100kΩ 1 68kΩ 1 30kΩ 4 10kΩ
1 4.7kΩ 1 3kΩ 2 2.2kΩ 1 1kΩ 1 270Ω 1 150Ω
1 9mm 10kΩ linear potentiometer (VR1) [Jaycar RP8510]

ment. The BTL configuration means when the voltage at the pin 8 output goes positive, the voltage at the pin 5 output goes negative and vice versa.

This results in twice the voltage across the speaker compared to that at either output pin, giving up to four times the output power ($V^2 \times R$). It also eliminates the need for a coupling capacitor, since both ends of the speaker are driven with the same DC bias level.

When headphones are plugged into CON3, the internal switch is open and so the HP-sense input (pin 3) of IC3 is pulled to +5V by the connected 100kΩ resistor. This shuts down the pin 8 output, making it high impedance and thus muting any speaker connected via CON2.

It also reduces IC3's power consumption when driving headphones, since the second internal amplifier is also shut down and not drawing any current.

With headphones not plugged in, the switch contact closes and the 150Ω resistor pulls pin 3 below 50mV. This enables the BTL drive arrangement for the speaker.

IC3 has a DC volume control input at pin 4. Potentiometer VR1 is used to adjust the voltage at this pin between 0V, for minimum volume, through to about 4.1V for maximum volume, when wound fully clockwise. The 4.1V maximum level is achieved using a 2.2kΩ padding resistor between VR1 and the +5V supply.

Power supply

Both IC1 and IC3 need a 5V supply so the entire circuit is powered from the 5V supply rail. This is provided by linear regulator REG1, which is fed by 9V from the battery or 6-12V DC from a plugpack connected via CON1.

REG1 has a low quiescent current and a low dropout voltage, meaning it won't drain the battery too fast and it can provide a steady 5V output even when the battery voltage is barely above 5V.

Schottky diode D1 provides protection in case either supply is connected with incorrect polarity. Also, the switch within DC barrel socket (CON1) disconnects the battery when a DC plug is inserted.

The unit is powered on or off using toggle switch S1. Blue LED1 lights up when it is on. This LED has a 3V voltage drop and diode D2, which is connected in series, has a forward voltage of around 0.7V. This means that the LED will only light if the regulator output is above about 3.7V.

In fact, the LED will be very dim unless the supply is close to 5V. So LED1 is not only a power indicator but it also works as a battery voltage indicator, showing when REG1 drops out of regulation as the battery becomes discharged. So when LED1 becomes very dim or goes out entirely even when S1 is on, you know it is time to replace the battery.

Construction

The Tinnitus and Insomnia Killer is designed to be housed in one of two similar (but slightly different size) cases.

There are two different PCB designs. One is coded 01110181 and measures 63.5mm x 86mm, which suits the Jaycar HB5610 case (135 x 70 x 24mm).

The other is coded 01110182 and measures 58.5 x 86mm; this one suits the Altronics H0342 case (130 x 68 x 25mm).

We have also produced panel labels to suit both boxes. Before starting assembly, make sure you have the correct PCB to suit your chosen case. They are shaped to fit inside the respective case and mount onto the integral plastic posts.

Use the appropriate PCB overlay diagram, either Fig.5 (01110181) or Fig.6 (01110182) and the matching photo (built into the Jaycar case) as a guide during assembly.

Start by fitting surface-mount IC3. This is soldered directly to the PCB. First, check the overlay diagram for the correct orientation, then tack solder one pin to the board.

Some constructors find that using a wooden clothes peg (not plastic – it melts!) helps to hold small SMD components in place while soldering the first pin.

Re-check the orientation and that all the pins are positioned correctly over their pads before soldering the remaining pins. If it is misaligned, remelt the solder on the first pin and adjust its position. Any solder bridges between the leads can be cleared by adding a small amount of flux paste and then using solder wick to draw up excess solder.

Next, mount the resistors. Use the resistor colour code table as a guide, but we still recommend that you measure each value using a digital multimeter before fitting them because some colours can be easily confused, especially under low light.

You can then install the diodes. These must be mounted with the orientation as shown. D1 is a 1N5819 type while D2 is a smaller 1N4148 type.

IC1 should preferably be mounted in an IC socket, while IC2 can be soldered directly to the PCB. When installing the socket and ICs, take care to orientate them correctly. The small dimple marking pin 1 must be positioned as shown in the relevant overlay diagram.

REG1 mounts horizontally on the PCB with the leads bent down 90° to insert into the holes. The metal tab is secured to the PCB with an M3 screw and nut.

Make sure you bend the pins down and tighten the screw *before* soldering the leads; otherwise, when you do it up, you could crack the solder joints.

The capacitors can be mounted next, starting with the MKT types. There are two options for the 27nF capacitor, as mentioned in the parts list. It's easiest to use a single 27nF capacitor but if you can't get one, you can solder a 22nF capacitor in its place on the top of the PCB and add a 4.7nF capacitor mounted on its side under the PCB (so they're soldered in parallel).

The electrolytic types should go in next and once again, they must be orientated with the polarity shown, ie, with the longer (positive) lead through the hole nearest the + symbol on the PCB. The stripe on the can indicates the negative lead.

Make sure these capacitors are mounted hard down in the PCB surface, so their height above the PCB is no more than 12.5mm; otherwise, the lid of the case will not fit correctly.

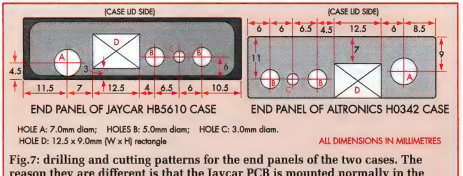


Fig.7: drilling and cutting patterns for the end panels of the two cases. The reason they are different is that the Jaycar PCB is mounted normally in the case, whereas the Altronics PCB is "hung" upside down from its case lid (which becomes the front panel). The rectangular cut-outs can be made by drilling a series of small holes around the outside, then carefully filing the hole to shape.

The potentiometer (VR1) and PCB-mounted switches S1 and S2 can now be fitted, along with the DC socket (CON1), the terminals for the loudspeaker (CON2) and the 3.5mm jack socket (CON3).

Finally, solder LED1 in place. It's mounted with its lens horizontal, centred at a height of 6mm above the PCB. Bend its leads at 14mm back from the base of the lens through 90°, making sure the longer anode lead is to the left.

Testing

Apply power (either from a 9V battery or plugpack) and check that LED1 lights and that REG1 provides a 5V output, measured between its metal tab and the right-hand lead (nearest the edge of the PCB).

Also, check for 5V at pin 1 of IC1, pin 8 of IC2 and pin 1 of IC3. Pins 3 and 5 of IC2 should be at around 2.5V.

Turn volume control VR1 down to zero (maximum anti-clockwise) then plug in a pair of headphones or earbuds. Put them on – you should hear nothing – then slowly turn VR1 up and check that you can hear the sound output.

Unplug the headphones and repeat the above check with an external speaker connected to CON2 now. You should be rewarded with an increase in noise as you increase VR1.

For both earphones or speakers, pink noise is produced when switch S2 is in the up position and white noise when it is down.

Preparing the case

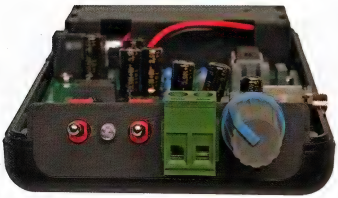
Because all the controls and sockets are mounted directly

Resistor Colour Codes

No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑ 2	1MΩ	brown black green brown	brown black black yellow brown
❑ 1	100kΩ	brown black yellow brown	brown black black orange brown
❑ 1	68kΩ	blue grey orange brown	blue grey black red brown
❑ 1	30kΩ	orange black orange brown	orange black black red brown
❑ 4	10kΩ	brown black orange brown	brown black black red brown
❑ 1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑ 1	3.0kΩ	orange black red brown	orange black black brown brown
❑ 2	2.2kΩ	red red red brown	red red black brown brown
❑ 1	1kΩ	brown black red brown	brown black black brown brown
❑ 1	270Ω	red violet brown brown	red violet black black brown
❑ 1	150Ω	brown green brown brown	brown green black black brown

Small Capacitor Codes

Qty.	Value	µF Code	EIA Code	IEC Code
❑ 1	220nF	0.22µF	224	220n
❑ 3	100nF	0.1µF	104	100n
❑ 1	33nF	0.033µF	333	33n
❑ 1	27nF	0.027µF	273	27n
❑ 2	22nF	0.022µF	223	22n
❑ 1	10nF	0.01µF	103	10n
❑ 1	4.7nF	0.0047µF	472	4n7



End-on view of the controls of the Tinnitus & Insomnia Killer – again, this is the Jaycar case version. No label is needed as markings are on the front panel .

on the PCB, it is essential that they are drilled/cut out in the proper position.

Use Fig.7 as a guide for locating and sizing these holes. You can also download this diagram as a PDF file from the www.siliconchip.com.au website, print it and use it as a template.

Most holes can simply be drilled (with care) but the 12.5 x 9mm rectangular hole (for the speaker terminal block) is made by drilling a circular hole or series of holes within the perimeter and then filing it to shape.

Holes are also required in the sides of the case for the DC socket and 3.5mm jack socket. Place the PCB in the case and mark out the positions for the holes required.

The Jaycar case has a removable end panel which makes drilling a little easier.

But the Altronics case does not have such a panel – in this case the PCB mounts upside-down on the lid. Therefore the holes are in a different position to those in the Jaycar case.

Also, you will need to remove the retaining clip from the plug for CON2 with side cutters, as this will foul the panel and case if left intact, preventing its insertion.

Final assembly

For the Jaycar case, the battery snap is inserted from the battery compartment side and the leads pass through to the PCB. They are routed through two 3mm holes for strain relief, as shown in Figs. 5&6.

Solder the ends directly to the plus and minus pads, ensuring that the red lead goes to the pad marked plus. The PCB is secured to the base of the case using four self-tapping screws for the Jaycar version and using three screws for the Altronics version, into the integral mounting bushes.

If you purchased the optional belt clip for the Altronics case, attach it now, then attach the lid to the case using the four screws supplied with the case.

Front panel label

To produce a front panel label, you have several options. Easiest and quickest is to simply photocopy (or download and print) a label on bond paper, cut it out and glue it to the panel. However, this will not last long without protection – self-adhesive clear plastic film will help.

The labels can be downloaded from siliconchip.com.au/Shop/2018/11

Or you could print onto clear overhead projector film with a flipped image (using film suitable for your type of printer) and attach to the lid with white or grey silicone sealant, with the printing on the underside. The label will then read correctly from the outside, while protecting the label from damage.

Alternatively, you can print onto a synthetic "Dataflex" sticky label that is suitable for inkjet printers or a "Datapol" sticky label for laser printers. After fixing the label to the panel, cut out the required holes with a hobby knife.

For more information on making this type of label, see siliconchip.com.au/Help/FrontPanels

Fig.8: 1:1 front panel artwork for the Jaycar case (left) and the Altronics case (right). They are slightly different sizes to match the different case sizes.These can also be downloaded from siliconchip.com.au for you to print.

Which speaker to use?

Just about any 4 or 8-ohm speaker can be pressed into service. Maximum power is only 750mW so you're not likely to blow anything up!

And contrary to popular belief, larger speakers generally do not require more power to drive than smaller speakers, as they are (usually!) more efficient.

Therefore, the larger one will usually sound "louder" than a smaller one for a given power input.

So if you want to use that old speaker box gathering dust in the cupboard, go right ahead! SC

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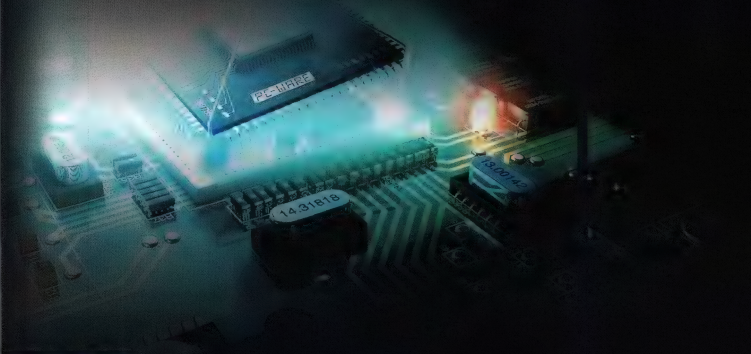

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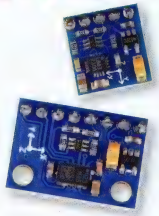
Two tiny Electronic Compass modules



The Elecrow GY-271 and the GY-511 are two low-cost electronic compass modules. Both readily available modules incorporate a 3-axis magnetometer, with the GY-511 also including an accelerometer. You can use them with an Arduino, Micromite or any other microcontroller which supports I²C communication.

The GY-271 is the smaller of the two modules, measuring only 14.5 x 13.3 x 3.5mm (without the 5-pin header attached). It's based on the Honeywell HMC5883L 3-axis digital compass (magnetometer) IC, which is no longer being manufactured but is nevertheless still available in significant quantities.

The GY-511 is nearly double the size, measuring 21 x 14.5 x 3.5mm (without the 8-pin header attached). This module is based on the STMicroelectronics LSM303DLHC 3D accelerometer/3D magnetometer IC, which is somewhat more complex than the HMC5883L.

A functionally identical clone of the GY-271 is available from Altronics (Cat Z6391) and Jaycar (Cat XC4496). This has a six-pin header rather than five, with the extra pin being a 3.3V output from the on-board regulator which you can use to power external circuitry.

Since that connection is purely for convenience, the description of the GY-271 here applies to those modules too.

The GY-511 is also available from Altronics, Cat Z6391A. Interestingly, while the GY-511 is a bit more expensive overseas, Altronics charge exactly the same for it as they do the GY-271 clone. Given the extra functionality, that seems like the one to get.

The HMC5883L

The HMC5883L IC used in the GY-271 module comes in a tiny 3 x 3 x 0.9mm 16-pin LCC (leadless chip carrier) surface-mount package. A simplified version of its internal block diagram is shown in Fig.1.

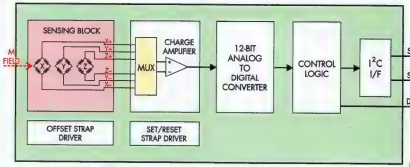
There are actually two chips inside the HMC5883L: the sensing block on the far left (pink shading) which does the actual magnetic field sensing and the measurement and control circuitry which forms the rest of the device. Presumably, this is necessary because they use different manufacturing processes.

The sensing block chip has three magneto-resistive sensor bridges, orientated at right angles to each other. They are labelled X, Y and Z. This allows it to sense both the direction and magnitude of very low-intensity magnetic fields, like the one generated by the Earth.

The sensor bridge outputs are connected to the inputs of an analog multiplexer (MUX) on the measurement chip, which allows the control circuitry to select them in turn.

The selected bridge output is then passed via a charge amplifier to the input of a 12-bit ADC (analog-to-digital converter), which delivers its corresponding digital value to the control logic section.

When all three measurements have been made in this way, the control logic makes them available to an external



HMC5883L eCOMPASS DEVICE INTERNAL BLOCK DIAGRAM

Fig.1: block diagram for the Honeywell HMC5883L eCompass IC, showing the magnetic sensing bridges at upper left, which are connected to the charge amplifier by a multiplexer.

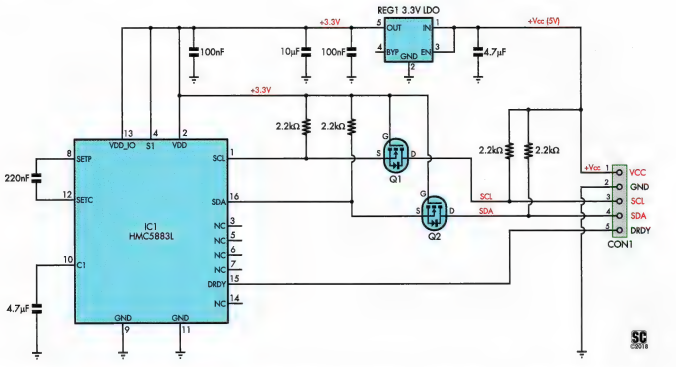


Fig.2: circuit diagram of the GY-271, which is based around the HMC5883L IC. It has few other components; primarily, voltage regulator REG1, level shifting Mosfets Q1 & Q2 and some bypass/filtering capacitors and pull-up resistors.

MCU via the standard I²C interface at far right.

The other two circuit blocks labelled "Offset Strap Driver" and "Set/Reset Strap Driver" are used by the chip's control logic to perform degaussing, testing and offset compensation for the magneto-resistive sensor bridges. As a result, the device can offer magnetic field resolution down to 200nT (nanoTesla) or 2mG (milliGauss).

This makes it very suitable for measurements of the Earth's magnetic field, which tends to vary between about 22µT and 64µT (microTesla) over the planet's surface. And it can make these measurements at a rate of up to 160Hz.

The supply current of the HMC5883L is very low, varying from around 2µA in idle mode up to about 100µA when it's making measurements. This makes it suitable for portable and hand-held applications like smartphones and tablets.

The circuit diagram of the complete GY-271 eCompass module is shown in Fig.2 with the HMC5883L forming the heart of this module. The only other active devices are REG1, a 3.3V LDO (low-dropout) regulator and N-channel Mosfets Q1 and Q2 which perform level translation on the SCL and SDA lines of the module's I²C interface.

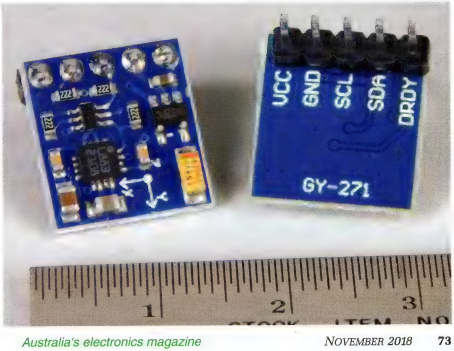
This means that the HMC5883L can operate from a 3.3V supply rail but still exchange data with an external micro running from a 5V supply. In fact, the I²C pull-up resistors (2.2kΩ) for CON1 connect to the incoming 5V supply.

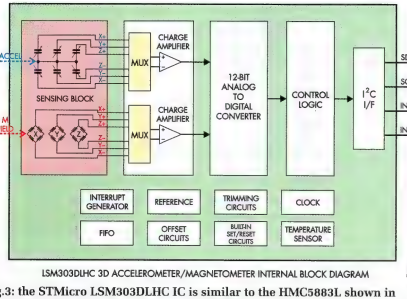
The 220nF capacitor between pins 8 and 12 of IC1 determines its Set/Reset timing, while the 4.7µF capacitor from pin 10 to ground acts as a reservoir for the charge amplifier ahead of the ADC. Pin 15 provides a data ready signal at the end of each measurement cycle. This is brought out to pin 5 of CON1, for optional use by the MCU to which it's connected.

We'll describe how to use this module a bit later. First, let's take a look at the IC used in its larger sibling, the LCM303DLHC.

The LSM303DLHC IC

Fig.3 shows a simplified block diagram of the LSM303DLHC eCompass IC, and as you can see it is a little more complex than the HMC5883L (Fig.1).





LSM303DLHC 3D ACCELEROMETER/MAGNETOMETER INTERNAL BLOCK DIAGRAM

Fig.3: the STMicro LSM303DLHC IC is similar to the HMC5883L shown in Fig.1 but also incorporates a three-axis MEMS accelerometer along with an additional multiplexer and amplifier. This allows the compass' orientation to be determined, for more accurate results.

Most of the additional complexity is because this device incorporates a 3-axis linear accelerometer as well as the 3-axis magnetometer.

The magnetometer's sensing system is similar to that in the HMC5883L, with three magneto-resistive sensor bridges orientated at right angles to each other.

The linear accelerometer sensors are made from very thin micromachined strips, again orientated in mutually orthogonal directions, which cause capacitance changes when they deflect in response to any acceleration forces.

They can also be used to sense gravitational fields, which allows the Earth's gravitational field to be used for calibrating the magnetometer.

Both sensor arrays are shown in the pink shaded area of Fig.3 and they each have their own multiplexer and charge amplifier feeding the in-built ADC. The only other real differences from the HMC5883L are the additional blocks shown at the bottom of Fig.3.

Either of the two sensing arrays can be enabled or disabled by the control logic, in response to commands sent from the host MCU via the I²C interface.

Since the accelerometer array is not really needed when you want to use the device as a simple eCompass, it can therefore be disabled. So when used as an eCompass, the LSM303DLHC is quite similar to the HMC5883L.

The LSM303DLHC draws about 110µA in normal measurement mode and around 1µA in idle/sleep mode. It has seven magnetic measurement ranges varying from ±1.3 gauss to ±8.1 gauss (1G = 100µT), a maximum magnetic resolution of 2mG (0.2µT or 200nT) and the ability to make measurements at eight selectable rates, from 0.75Hz to 220Hz.

So once again, the LSM303DLHC IC forms the heart of the GY-511 eCompass module, as shown in Fig.4. If you compare this with Fig.2, you'll see that they're almost identical.

The only differences are the chip for IC1 and an 8-pin header for CON1 instead of a 5-pin header. When using the GY-511 module as an eCompass, the additional pins can be ignored.

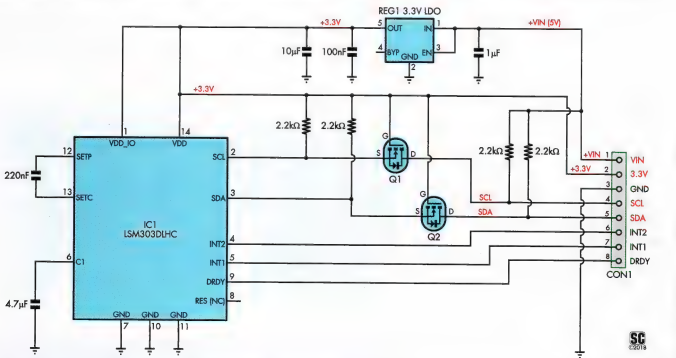
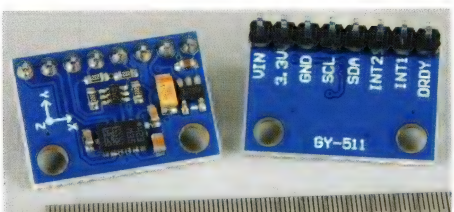
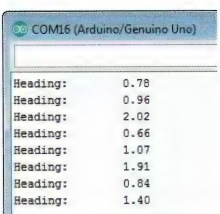


Fig.4: the circuit for the GY-511 eCompass module, which is virtually identical to the GY-271 shown in Fig.2, except that a different IC is used and it has two extra interrupt signal connections which are wired to header CON1This has more pins (eight, compared to five), along with a 3.3V output from REG1.





The GY-511 module shown enlarged above and to its right is the example serial output from the Compass.ino sketch (James Sleeman's Arduino library) using the GY-271.

Connecting to a micro

As both modules use an I²C serial interface to exchange data with an MCU, connecting them to an Arduino or a Micromite is straightforward.

Fig.5 shows how a GY-271 is connected to an Arduino, while Fig.6 shows how it's connected to a Micromite. Similarly, Fig.7 shows how a GY-511 module is connected to an Arduino, while Fig.8 shows how it's connected to a Micromite.

Things are not quite so straightforward when it comes to the software. You would expect that there are already Arduino libraries suitable for interfacing with these modules, and indeed they are available. But when I tried them out, I found most of them to be too complicated, poorly written and/or buggy.

The only library I found that was both easy to use and worked well was one called HMC5883L_Simple, written by James Sleeman in New Zealand. This library can be downloaded from Mr Sleeman's website, at: http://sparks.gogo.co.nz/HMC5883L_Simple.zip

The archive file includes a simple example sketch (Compass.ino), which I can recommend. A sample grab of the Arduino IDE's Serial Monitor output when running this sketch is shown above, with the GY-271 module's Y axis pointing to magnetic north. The heading figures are all within the range of 0.43-2.14°N.

Since the two modules are similar, we adapted this library to work with the GY-511 module without any modifications, although the magnitude of the results may be wrong (this isn't terribly important when using it as a compass).

When it comes to using either of these modules with a Micromite, I couldn't find any existing programs or libraries.

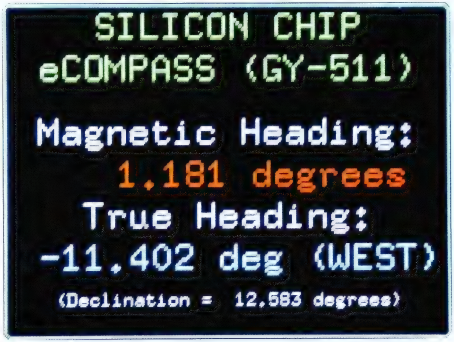
So I had to analyse the functions embedded in Arduino libraries (especially Mr Sleeman's), and then write MMBasic programs to duplicate the same functions on the Micromite.

The programs I wrote are called "GY271 eCompass.bas" and "GY511 eCompass.bas" and both are available in a zip file from the SILICON CHIP website. Note that all of these programs (Arduino and Micromite) treat the Y-axis of the module as the "needle" of the eCompass.

These programs do the bare minimum to allow the modules to be used as electronic compasses. They initialise the main IC, then make measurements twice a second, process the X and Y data readings to arrive at the magnetic heading, then convert this to a true heading by subtracting the local declination figure.

Both heading figures are then displayed on the Micromite's LCD screen, as you can see from the screenshot below. Note that the current declination is also shown at the bottom of the screen, as a reminder.

The declination adjustment is necessary because the Earth's magnetic North Pole is not at the actual North Pole; in fact, they are getting further



Our example MMBasic program shows both the magnetic heading (relative to north magnetic pole) and the true heading (relative to the north celestial pole).

Fig.5: connecting the GY-271 eCompass module to an Arduino is easy as it only requires four connections: two for 5V power and two for I²C communications (SDA [data] and SCL [clock]). The DRDY signal is not mandatory.

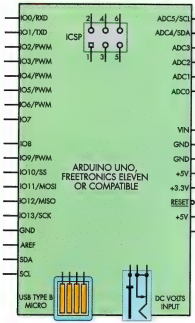
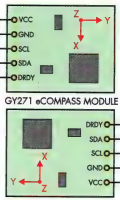
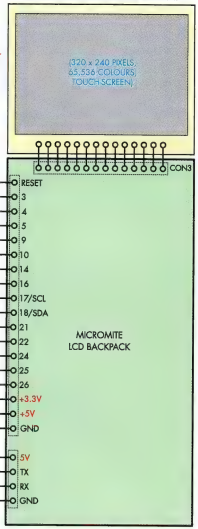
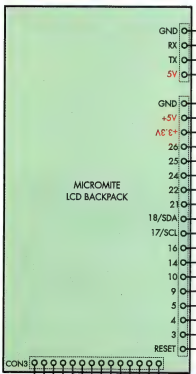


Fig.6: connecting the GY-271 to a Micromite (in this case, the LCD BackPack) is just as easy; the connections are the same as in Fig.5 but the Micromite uses pins 17 and 18 for I²C communications.







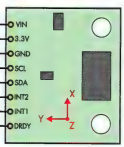
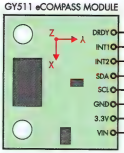


Fig.7: connecting the GY-511 module to an Arduino involves similar wiring compared to the GY-271. As with the DRDY signal, the two interrupt signals are not absolutely necessary and so can be left unconnected.



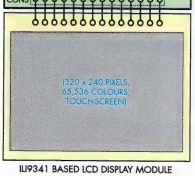
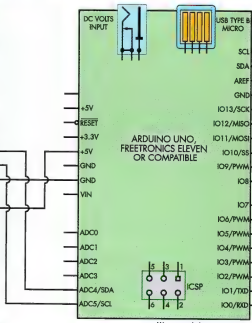


Fig.8: as with the Arduino circuit in Fig.7, only four pins of the GY-511 need to be connected to the Micromite (two are for the power supply and two are for I²C serial communications).



How a compass works

A compass is a portable device used to work out your heading. This is the direction in which you are travelling with respect to the Earth's axis of rotation, or the hypothetical meridian lines on the surface of the Earth between the true south and North Poles. It does this by sensing the weak magnetic field which surrounds the Earth, due to the magnetisation of the Earth's metal core.

A traditional compass senses the Earth's field by means of a small magnetised iron needle which is able to rotate freely in the horizontal plane about its centre because it's either floating on a small pool of liquid or mounted at its centre on a very low friction needle bearing.

As a result, the needle can orientate itself to align with the horizontal component of the Earth's field, so the needle always tends to point towards north. A dial around the circumference of the compass then allows the user to work out the direction of any desired heading.

That's the basic idea, anyway. But in practice, things are a little more complicated. That's because while the compass needle aligns itself with the Earth's magnetic field passing from south to north, that field passes between the Earth's magnetic poles and these are different from the Earth's true geographic poles (which correspond to its axis of rotation).

Not only that, but the magnetic field is not uniform with smooth meridian lines passing between the South and North Magnetic Poles. In fact, the field lines weave around quite a bit, with an orientation varying significantly according to latitude and longitude and also according to time, as the field pattern changes from year to year.

So wherever you happen to be, although the needle of a compass nominally points towards north, that doesn't mean that it shows the direction of true north. To work out the direction of true north, you need to know the angle between the horizontal component of the Earth's magnetic field at that location and a meridian line from the true South Pole to the true north pole at the same location.

TABLE 1: Magnetic Declination & Inclination figures in our area

LOCATION	DECLINATION	INCLINATION
Adelaide SA	+8° 1'	66° 59'
Alice Springs NT	+4° 34'	55° 31'
Brisbane QLD	+11° 3'	57° 35'
Broome WA	+1° 46'	48° 34'
Cairns QLD	+6° 47'	45° 22'
Christmas Island	+0° 22'	38° 05'
Darwin NT	+2° 38'	39° 44'
Hobart TAS	+15° 10'	72° 38'
Melbourne VIC	+11° 41'	68° 49'
Onslow WA	+0° 32'	54° 22'
Perth WA	–1° 50'	66° 08'
Rockhampton QLD	+9° 15'	53° 19'
Sydney NSW	+12° 35'	64° 18'
Auckland NZ	+19° 58'	62° 51'
Christchurch NZ	+24° 10'	68° 38'
Dunedin NZ	+25° 47'	70° 46'
Invercargill NZ	+25° 44'	71° 32'
Wellington NZ	+22° 43'	66° 32'
Dili TIMOR-LESTE	+1° 28'	32° 56'
Jakata INDONESIA	+0° 38'	29° 49'
Kuala Lumpur MALAYSIA	+0° 1'	9° 49'
Port Moresby PNG	+5° 53'	33° 22'

NOTE: Positive declination = –> EAST, negative = –> WEST
Inclination is UPWARD towards north in Southern Hemisphere

This angle is called the Magnetic Declination and you can find the declination at any particular point on the Earth's surface by referring to either maps or websites like www.magnetic-declination.com

The declination varies quite significantly over Australia and New Zealand. For example, in Sydney, it's around 12.6°E while in Perth it's around 1.8°W. The current declinations for a number of locations in Oceania are shown in Table 1.

There's another aspect of the Earth's magnetic field that can affect compass operation. That's the fact that the magnetic field at any particular location is not aligned parallel to the Earth's surface (ie, in the horizontal plane) but in many places is at a significant angle.

This is called the Magnetic Inclination, and broadly speaking (when facing north) it points down into the ground in the Northern Hemisphere and upwards away from the ground in the Southern Hemisphere. This doesn't have a major effect on compass operation but it sometimes does need to be taken into account, especially with traditional compasses.

Table 1 also shows the inclination of the Earth's magnetic field for each location. All the inclinations listed are orientated upwards (because all locations are in the Southern Hemisphere) but they vary with latitude. The locations that are furthest south have a noticeably higher inclination than those nearer the Equator.

apart each year so you may need to update this value occasionally to maintain accuracy. See the panel above for more detail on the differences between magnetic north and true north.

Both programs are written to include the magnetic declination of Sydney (12.583°E, as shown in the previous screenshot). If you're at a different location, you need to modify the source code to include the correct declination value for your location, near the start of the program:

```
DIM AS FLOAT Declin! = 12.583
```

Like Mr Sleeman's Arduino library and example sketch, my Micromite programs make no allowance for the local inclination (tilt) of the Earth's magnetic field.

In this respect, they are the same as a traditional compass – both programs assume that the module's PCB (and thus its magnetometer chip) is being held in the horizontal plane or close to it.

It possible to take the magnetic inclination into account when working out the absolutely true heading of an eCompass but you need to combine the data from the magnetometer with that an accelerometer or gravity field detector like that in the LSM303DLHC chip. So you could not do this with the GY-271 module unless you also had a separate accelerometer.

This also requires quite a bit of number crunching to combine the data from the two sensors. Which raises the question of whether it would be worth the effort. Ignoring the inclination seems to deliver a heading accuracy that is at least as good as a traditional compass and probably better.

I think that the only applications where it would be necessary to achieve the highest possible heading accuracy would be for things like aircraft or ship navigation, or missile guidance systems. But those are a bit out of my league.

Handy links

HMC5883L datasheet:
siliconchip.com.au/link/aakz
LSM303DLHC datasheet:
siliconchip.com.au/link/aal0
Magnetic declination:
siliconchip.com.au/link/aal1
Geomagnetic declination:
siliconchip.com.au/link/aal2

SC

ACCURACY BETTER THAN 100 PARTS PER BILLION!

Lab Quality... Programmable... GPS-synched... FREQUENCY REFERENCE

µmite

Part 2

by Tim Blythman and Nicholas Vinen

Our new GPS Frequency Reference is *really* accurate, precise and flexible. It's also compact and easy to use, thanks to its touchscreen interface. You can set the frequencies of its three programmable outputs over a wide range (1-100MHz) and you can save preferred frequencies to a set of four presets for each output, to make switching between them quick and easy.

Last month we described the circuit of our new Frequency Reference project and gave some details on how the software worked. We also explained its general concept and how it achieves such flexibility and accuracy in the frequencies that it can produce.

This month, we have detailed assembly instructions and further information on how to use it, including all the various customisable settings.

While the settings all have sensible defaults, allowing you to build it and start using it without any fiddling, you can tune the software parameters to suit your particular requirements.

Construction is pretty straightforward, despite the use of mainly surface-mount components. There are just one or two that are slightly tricky but they are not that difficult, as long as you use the right tools and take your time to get it right.

Later in this article, we describe how the voltage-controlled oscillator (VCO), which forms the heart of this Frequency Reference, can be manually adjusted.

This can be handy if you have access to a high accuracy frequency meter or can't access a GPS signal – for example, if you're operating the unit in a basement or the middle of a steel-reinforced building.

Building the LCD Back-Pack

The first step is to build the Micromite LCD BackPack. You can use the original 2.8-inch version (described in the February 2016 issue; siliconchip.com.au/Article/9812) or the revised version from the May 2017 issue,

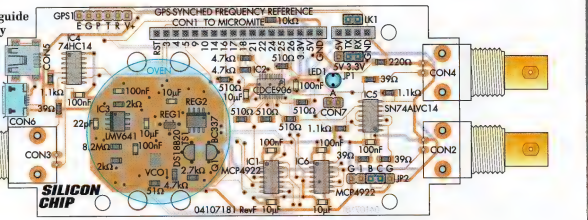


Fig.3: use this diagram as a guide when building the Frequency Reference. The orientations of IC1-IC6, LED1, REG2 and TS1 are critical so take care to fit them the right way around, as shown. You only need to fit one of CON5 or CON6, not both. Note the approximate location of the bottle cap or similar cylinder which encloses the oven section of the board.

which incorporates the Microbridge (siliconchip.com.au/Article/10652).

We used the latter in our prototypes. Note though that you cannot use the software-controlled backlight option if you build the BackPack V2 as this uses pin 26, which we have had to use for a different purpose on the Frequency Reference board.

So you need to omit Q1 and Q2 and fit VR1 instead. The backlight brightness is then adjusted using trimpot VR1, as it was on the original BackPack.

Both versions of the BackPack are available as complete kits from the SILICON CHIP Online Shop and can be purchased with the chip pre-programmed to suit this project (Cat SC3321 or SC4237).

We do not recommend that you use the Micromite Plus LCD BackPack as we have not tested it in this project. If you need assembly instructions for either kit, refer to the articles mentioned above.

But once you have the parts, the assembly is pretty easy, as only about 20 components are involved and the position/polarities of most of these are printed on the PCB.

Solder the components on the PCB where shown, being careful with the orientation of the IC(s), regulator and LED. The capacitors supplied in the kit will not be polarised types.

Start assembly with the lowest profile components first and work your way up to the taller ones.

Note that the 18-pin and 4-pin headers are mounted on the back of the board and these should be fitted last.

You can then plug the screen into the provided header socket and attach it to the BackPack board using short machine screws and tapped spacers.

Trim the solder joints on the top of the LCD with some sharp sidecutters, so they do not interfere with the lid when fitted later.

PCB assembly

Next, we'll assemble the Frequency Reference PCB. Use the overlay diagram (Fig.3) as a guide to fitting the components.

Before starting, check that you have all the components needed. If you have a kit of parts, don't pull them all out yet as some are hard to distinguish from others, especially those which have no markings (eg, ceramic capacitors).

We will refer to the orientation as though the board is sitting as shown in Fig.3, with the single BNC socket (CON3) at the left, and the two BNC sockets (CON2 and CON4) to the right.

This orientation is convenient since most of the labels are right-side-up.

It's easiest to start with the fine-pitch ICs first as these are more difficult to solder once surrounding components have been fitted. So start by fitting IC2, the CDCE906 PLL IC.

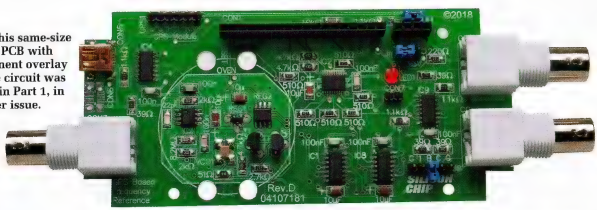
This part is only available in an SSOP SMD package with a 0.65mm lead pitch. It requires the most care to solder but it is not too difficult to do by hand if you are careful.

The other components are much larger and have leads spaced further apart so, after this chip, it's downhill all the way. Start by applying a thin layer of flux paste to the pads for IC2, then line up the chip with the pads, ensuring the pin 1 marking is to upper right.

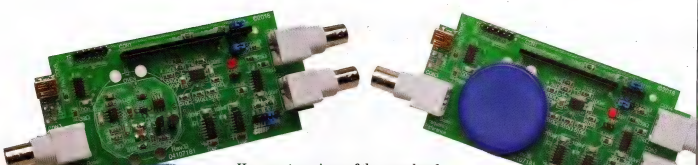
Using a fine-tipped soldering iron, tack solder one of the corner pins down and check that the all the IC pins line up in the centre of the PCB pads and that the IC is flat on the PCB.

If you are happy with the location of IC2, carefully solder each pin.

If you have used flux paste as recommended, simply touching the iron to the pin and pad at the same time should cause a small amount of solder to flow onto both.



Compare this same-size completed PCB with the component overlay above. The circuit was published in Part 1, in our October issue.



Here are two views of the completed PCB, along with our highly technical purpose-designed oven (in situ on the right). If it looks just like a milk bottle cap, then, ummmm . . .

You will need to add a bit of extra solder to the iron from time to time. At this stage, if there are solder bridges between pins, don't worry about them.

The important thing is to make sure that all the pins are soldered properly. Patience, and keeping the tip clean of impurities like dark oxides will make this process easier. Once all the other pins have been done, go back and retouch the first pin.

If you have some solder bridges (which are almost inevitable), apply some fresh flux and use solder braid (wick) to remove the excess.

Check deep between the pins, as a single hidden bridge is enough to cause trouble. We've found taking a photo with a smartphone camera can allow us to zoom in and see bridges and other defects that aren't immediately obvious to the naked eye.

Next on the list are the USB sockets, which can be a bit fiddly but fortunately, you only need to install one of them.

We chose the mini-USB socket as it is slightly larger and easier to handle but the micro-USB socket is now the more common type in use (especially on phones), so you can fit that if you prefer.

Again, start by putting a little flux paste on the pads. Place the socket on the PCB and its pegs should drop into the provided holes in the PCB, making alignment easier. Solder the large mechanical pads first, making sure the socket is flat and flush with the board.

Now carefully apply a little solder to each of the small leads to lock them in place. We only need the pins at either end for power but it's probably a good idea to solder them all anyway.

Be sure to check that the USB data pins are not bridged to the power pins, as this may cause problems if the GPS Frequency Reference is powered from the USB port on a computer.

You can now fit IC1 and IC4-IC6, using a similar process as for IC2. These are considerably larger and easier to handle.

Check that the pin 1 markings are correct. IC1, IC4 and IC6 have their dot facing upwards, while IC5 has its dot facing downwards.

If there is no dot, you might find a bar on one end of the IC or even a bevel along one edge. In each case, pin 1 is close to the dot/bar/bevelled edge.

Next on the list are REG1, REG2 and IC3, which are all within the oven outline. This is marked with a circle and there is also a corresponding copper pour on the PCB.

While this should not present any difficulties, you might find that the extra mass of copper pulls heat away from the iron, so you may need to turn its temperature up slightly to compensate.

If you are using the SOT-23 version of REG1 then it should be soldered first, as it is quite low. It will only fit one way, so tack one leg in place, check the alignment and then solder the other two leads and touch up the first pin.

If you are using the TO-92 version of REG1, you can fit it later, once all the SMDs are in place. IC3's pin 1 goes towards the upper left corner while REG2's pin 1 goes to the top right.

Solder these components using the same technique as the other ICs. Now is a good time to solder VCO1.

The pin 1 marking on this module is one of the smallest we have seen. If you cannot find it, then rotate your PCB so that CON3 is at the bottom. Then place the VCO on the board so that the writing on it is right-way-up. You might now see the small marking at the bottom left, matching the dot on the PCB.

For smaller components like this, adding a small amount of solder to one pad before placing the component means that you don't have to apply solder while trying to position the component.

Use tweezers to hold the component flat and aligned while adjusting its position, then when you are happy, solder the other leads in place.

The VCO's pads are much larger than necessary, to make it easier for you to get the iron in contact with them despite the tiny size of the device. Ensure VCO1 is symmetrical about the pads so that each one makes good contact.

Carefully apply more solder if necessary but avoid getting any near the top of the VCO, as it may stick to the metal can and cause problems later.

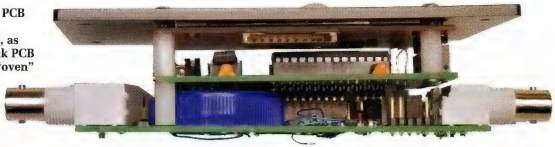
Passive components

The passives should be fitted next. The capacitors are not usually marked, so only take them out of the package one value at a time. Fortunately, they are not polarised. Fit them where shown in Fig.3.

Follow with the resistors. There are several different values but fortunately,

SMD Resistor Codes

❑	1	8.2MΩ	825 *or*	8204
❑	1	10kΩ	103 *or*	1002
❑	3	4.7kΩ	472 *or*	4701
❑	1	2.7kΩ	272 *or*	2701
❑	2	2.0kΩ	202 *or*	2001
❑	1	1.1kΩ	112 *or*	1101
❑	6	510Ω	511 *or*	5100
❑	1	220Ω	221 *or*	2200
❑	1	51Ω	511 *or*	51R
❑	4	39Ω	390 *or*	39R



The Frequency Reference PCB "hangs" underneath the Micromite BackPack PCB, as shown here. The BackPack PCB also holds the bottle cap "oven" in place. If you mount it differently, the cap will need securing to the PCB via the holes provided.

they are marked with codes indicating their values if you get them mixed up.

Fit them in the same manner as the capacitors and again, refer to the overlay diagram to see which goes where.

The final items are three 1.1kΩ resistors. You may have noticed that we had four 1.1kΩ resistors in our original parts list but there are only three on the board. We found that the resistor on IC2's Y4 output was limiting the swing on the 40MHz signal going back to the Micromite, so its frequency wasn't being measured accurately.

Thus, we removed this resistor from the final design.

Through-hole components

Now is a good time to fit Q1, TS1, LED1 and (if you are using the through-hole version) REG1. Ensure LED1 is inserted with its longer anode lead through the pad marked "A" on the PCB. The orientation of the TO-92 package devices is shown in Fig.3 but you may need to bend their leads out (eg, using small pliers) to fit the pads provided.

Now you can solder the headers in place. This includes CON1, GPS1, LK1, JP1 and JP2. These are all fitted on the same side of the board as the other components and, except, for CON1, they are standard pin headers.

CON1 consists of two female header sockets, one with 18 pins and one with four pins. You can cut these down from longer sockets if necessary.

When fitting the GPS header, be careful to ensure it is perfectly vertical since otherwise, it may be difficult to plug the GPS connecting wires into it later.

To make sure they will fit, it's best to plug the BackPack into the Frequency Reference board after soldering one or two pins on GPS1, so that you can check that the header clears the board above.

To help line the CON1 sockets up correctly, you can plug them into the corresponding headers on the Micromite LCD BackPack first and then insert them into the pads on this PCB and solder the pins in place. The final items to fit are the three BNC sockets, CON2-CON4. The large posts require a decent amount of solder to hold them in place (and heat to make those solder joints).

If you're building the unit into a larger box than specified, you could run some shielded cable out to chassis-mounted sockets.

Setting up the BackPack

If you haven't used a PIC pre-programmed with the software for this project, you will need to set up the LCD screen and touchscreen. You can do this by connecting a USB/serial adaptor to the 4-pin header and plug it into your computer, then open up a terminal program, select the correct COM port and set the baud rate to 38,400.

Reset the Micromite and you should receive a greeting banner in the console. If you don't, check the serial wiring, COM port, baud rate, power supply and that you have assembled the PCB correctly.

Assuming you do get the greeting, you can set up the display and touch controller by issuing the following commands:

```
OPTION LCDPANEL
    ILI9341, L, 2, 23, 6
OPTION TOUCH 7, 15
GUI CALIBRATE
```

You then need to use a sharp object (but not too sharp!) like a toothpick to press on the middle of the targets which appear on the screen. Once you've done that, you're ready to load the BASIC software for this project.

Loading the software

Now that the two PCBs have been assembled plug them together but leave all the jumpers off for now. The next step is to load the BASIC software onto the microcontroller.

If you have a PIC chip in your BackPack that was pre-programmed with the GPS Frequency Reference software then you can skip right to the testing stage.

We suggest that you then use the MMEdit software to upload the BASIC program and the following instructions assume you will be using this method. If you are familiar with using the Microbridge to upload HEX files directly to the chip then you can do that instead.

Open MMEdit and load the BASIC file for this project, which is available from the SILICON CHIP website. Connect the Micromite to your PC via the USB socket on the BackPack itself (not the one on the GPS Frequency Reference PCB). Under the Connect menu, select New and find your Serial port number, then select it. Set the baud rate to the rate your Micromite is set up for (the default is 38,400)..

Under the Advanced menu, ensure that the "Auto Crunch on Load" option is selected. This is necessary as the program will not fit into the flash memory without being "crunched". Press the button to upload the code and when it finishes, type

```
OPTION AUTORUN ON
```

into the console which appears and press Enter. This sets the program to run next time the unit is powered up.

Wiring up the GPS module

There is not much spare room in the specified enclosure for the GPS module and anyway, you will probably get better results by mounting it externally, as we have on our prototype.

Alternatively, you could use a module with an external antenna connector and mount a socket just above the USB power socket on the case.

Because the GPS header (GPS1) is so close to the BackPack board above it, we recommend that you use slim DuPont-style headers to make the connections.

The pins are labelled as follows:

V+ (module power supply),
R (goes to Rx/RxD on the module),
T (goes to Tx/TxD on the module),
P (goes to 1PPS output on the module),
G (GND) and
E (enable – connected to V+).

If you are not using the recommended module then your module may not have an enable pin, or it may require a different voltage. You will need to use a module with a 1PPS output and TTL serial interface.

Testing

Close the console and unplug the USB cable from the Micromite. Insert a jumper on the LK1 header. This will connect the VCO output to the Micromite's pin 12, and also ensure that the console does not start up and interfere.

Plug a powered USB cable into the USB socket on the GPS Frequency Reference PCB and observe LED1. It should fade on and off for a few seconds.

At this stage, everything should be working and the splash screen should now be shown. To follow the status of the startup, press the "Status" button.

The six lines at the bottom of the Status screen are the important ones to watch, as the top lines are mostly information taken from the GPS module's NMEA data.

You may not see all items go to "OK" in the startup page straight away, particularly the GPS related items, as the GPS module usually takes some time to achieve a satellite fix.

If you are using the VK2828 GPS module, you will know when it has a fix, as the green LED on it will start flashing.

The "Temp Sensor" line should read "OK" and the temperature should be rising or near the setpoint. That means the oven is working correctly.

If "Temp Sensor" shows "Not ready" then TS1 is not wired correctly. If "Temp Sensor" shows "OK" but the temperature is not rising, there is a problem with Q1, the 2.7kΩ resistor or DAC IC6. If the LED was fading initially then the DAC is probably working.

There are three lines which indicate the status of the GPS module. The first one to check is "GPS Receiver". If that does not show "OK" then no data is being received and you should check the GPS module's wiring.

The "GPS 1PPS" and "GPS Locked" status lines will typically be the last ones to show "OK", as they depend on the GPS module having a good satellite fix. If you are testing indoors, you may find they flick between "OK" and "Not ready".

The "PLL unit" and "VCO output" lines are only updated at startup, so will not change if left for a while. If "PLL unit" does not show "OK" then the Micromite cannot communicate with IC2.

This may be due to problems with the I²C bus.

"VCO output" shows OK when the Micromite detects a ~40MHz signal. That means that the PLL and VCO are working to some extent. If there is no "VCO output" then check that the VCO chip is soldered to the PCB correctly.

As the 40MHz signal to the Micromite is also fed through the PLL (IC2), you should confirm that there aren't any problems with IC2 as well, eg, solder bridges between pins or bad solder joints.

Another test that you may like to do if you have an oscilloscope or frequency counter is to check that there is an output from each of the BNC sockets (or the JP2 header).

Assuming that JP2 is set to the "BC" position, all of CON2, CON3 and CON4 should be producing a 40MHz signal. If this is the case, then it is time to complete assembly.

Finishing the oven

While you would have seen the temperature of the oven increasing on the status page, and the unit is effectively functional, we can add some insulation to the oven to improve its ability to hold heat.

This helps to ensure that the temperature inside the oven is uniform, so that the temperature measured by TS1 more closely reflects the temperature of the other components inside the oven.

We've sized the oven to be roughly the same diameter as a bottle cap from a two-litre milk bottle.

We've found that most of them also have a foam insert which provides extra insulation

The height of our cap was precisely 12mm, which matches the tapped spacers between the two boards. Unfortunately, due to the components on the Micromite BackPack PCB, the available space is reduced slightly, and the rim of the bottle cap will probably need to be trimmed.

It's a good idea to give the lid a thorough clean with soap and hot water to ensure there is no milk residue.

We can imagine nothing worse than a GPS Frequency Reference that smells like mouldy cheese!

If the lid is a snug fit between the Micromite BackPack PCB and the GPS Frequency Reference PCB, it can simply be sandwiched in place. Otherwise, holes are provided on the PCB for cable ties to hold it in place.

Alternatively, you could use a small amount of neutral-cure silicone sealant around the rim to seal it and stop it from moving around.

The underside (ie, non-component side) of the PCB should ideally be insulated as well.

You could either use a foam insert from another milk bottle (held in place by the same cable ties) or merely apply some foam-backed double sided tape to the back of the PCB.

PCB jumper settings

The jumper on JP1 selects whether the GPS module receives 3.3V or 5V. Most modules will run off 3.3V, including the VK2828U7G5LF but if you are not sure, check the module's data sheet.

Fit a jumper shunt between the pins labelled B and C on JP2 if you want a programmable frequency on CON2. Alternatively, fit the shunt between the pins labelled 1 and B for a (disciplined) 1PPS (1Hz) output from CON2.

The pins labelled "G" are connected to ground so you can run a shielded cable from the pairs of pins at either end to a chassis connector if you want to make both of these signals available externally.

A shunt is placed on LK1 for normal operation but this prevents programming the Micromite chip, so remove it if you need to reprogram the chip. CON7 is for debugging the software so you can safely ignore it unless you plan to modify the software.

Putting it all together

Now power down the GPS Frequency Reference and detach the Reference PCB from the BackPack. If the BackPack display is attached by screws, remove them to allow the front panel to be fitted.

Assuming everything is apart, start by attaching the LCD to the laser-cut acrylic UB3 lid panel, using M3 machine screws at the front and tapped spacers at the back.

Insert 1mm Nylon washers between the lid and LCD to provide clearance for the solder joints.

Use 20mm-long machine screws on the bottom left, bottom right and top right holes. This is with the touch panel orientated so that its flex connector is on the right, along with the 14-pin header.

For the top left machine screw, use one of the shorter ones initially fitted to the LCD BackPack, again with a tapped spacer on the back.

This is necessary because a fourth long screw would interfere with the GPS header.

The Micromite BackPack PCB can now be inserted over the three long machine screws shafts and can be loosely secured with a short machine screw into the single tapped spacer.

Now feed the tapped spacers over the three remaining screw shafts. Ensure everything is tight and lines up. In particular, check that the LCD's screen is flush with (or slightly behind) the lid panel.

Finally, attach the GPS Frequency Reference PCB to the back of the Micromite BackPack PCB using the three remaining short machine screws from the original BackPack kit.

Putting it in the box

The enclosure specified is a standard UB3 Jiffy box. You will need to make cutouts at two ends for the BNC and USB sockets; see Fig.4 for details. You only need to make one of the cutouts for the mini-USB and micro-USB socket, depending on what you fitted to the board.

We used a stepped drill to make the BNC socket holes although you could use a standard drill and then enlarge them to size with a tapered reamer.

We made the vertical slot for CON3 using a hacksaw, cutting straight down from the top of the side of the box.

The holes for the USB sockets can be started with a small drill bit and completed with a file.

If you are feeling lazy, or don't enjoy cutting square holes, you could make (slightly larger) round holes for the USB sockets.

You may find that you have to make the hole larger than shown in the diagrams if the shroud on your USB plug is unusually large.

The final step is to carefully thread CON2 and CON4 into the holes in the right-hand side of the case and then lower CON3 down into its slot. Check that all the holes line up and that a USB cable will plug in. Then attach the acrylic lid to the Jiffy box using the supplied screws (or longer ones, if the ones that came with your box are too short) and fit the nuts and washers to the BNC sockets.

Using it

As you are reading the following instructions, you may wish to refer back to the first article on this project in last month's issue, as it included images showing many of the screens described below.

Once power is applied via the USB socket, the start screen will show for three seconds, after which the main screen appears. Press the STATUS button to check that everything is working as expected. The BASIC program is quite busy processing data, so sometimes it is necessary to press on the buttons for more than a brief 'tap'.

The Temperature line shows the current oven temperature and setpoint, followed by the oven heat controller DAC output, where zero is off and 4095 is full power.

After the unit has tuned itself and the oven temperature has reached its set point, it will provide a high degree of accuracy.

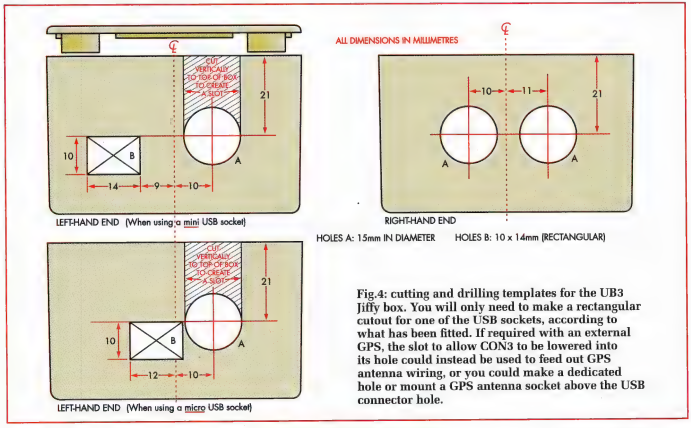


Fig.4: cutting and drilling templates for the UB3 Jiffy box. You will only need to make a rectangular cutout for one of the USB sockets, according to what has been fitted. If required with an external GPS, the slot to allow CON3 to be lowered into its hole could instead be used to feed out GPS antenna wiring, or you could make a dedicated hole or mount a GPS antenna socket above the USB connector hole.

If your workbench area typically gets above the 35°C we have set for the oven, you may need to make the setpoint a bit higher, so that the oven has a consistent temperature in all conditions.

See the Settings section below for details on how to do that.

The "GPS 1PPS" and "GPS Locked" status lines need to show "OK" before oscillator disciplining occurs but once the unit has got past the start screen, it is effectively operational, although it will not yet be operating with full accuracy or precision.

The tuning algorithm waits until it has received 1000 1Hz pulses with GPS lock, then calculates the average oscillator frequency (as seen on the top line) and adjusts the VCO control voltage to bring it closer to 40MHz.

Given that 1000 pulses take about 17 minutes and it takes some time for the GPS receiver to get a satellite fix, it should begin tuning itself within about half an hour of power-on.

You can explore the features of the unit before it has fully tuned itself; the initial tolerance on the VCO is 2ppm, which makes it a useful tool straight away.

Pressing the "BACK" button to go back to the main menu, you can jump straight into any of the adjustment pages for CON2-CON4 to set their output frequencies.

Note that these labels are adjacent to their respective BNC sockets, which helps you to remember which is which.

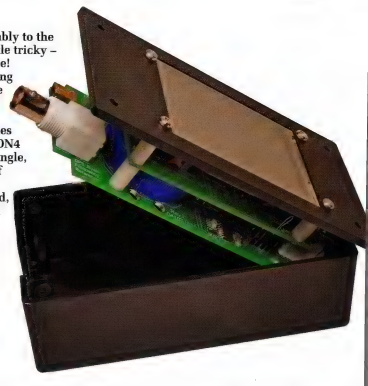
Once you've entered one of the output setup screens, the "SEEK F" button allows a frequency to be entered on a keypad and the unit will find the nearest frequency that it can synthesise to what you enter.

It will show the frequency, the various PLL dividers and even the PLL's internal frequency to allow you to decide if that particular combination is suitable.

Pressing "OK" will then update the PLL parameters to those shown and the new frequency will be immediately available from that output socket. Press "CANCEL" to go back to the output setup screen without changing the output frequency.

Manually setting up the PLLs

The "ADVANCED" page permits manual selection of the N, M and P dividers in the PLL, except for CON4, where only the P value can be changed; the N and M values are fixed because this PLL is shared with the output that provides VCO feedback to the Micromite.



Fitting the assembly to the UB3 case is a little tricky – but it can be done! After drilling/filing the required case holes, you need to introduce the boards to the holes for CON2 and CON4 at a quite steep angle, as shown here. If your holes are accurately drilled, the board should slip into place quite easily . . .

As explained last month, the incoming 40MHz signal is multiplied by N and divided by M to give the PLL frequency and then divided by P to give the output frequency.

While the PLL is supposed to operate between 80MHz and 300MHz, we found that it worked outside this range (perhaps with more jitter). The PLL frequency is displayed near the top of the page, and if it would be out of range, it is displayed in yellow. In this case, you should verify that the output frequency is accurate and stable.

If the resultant output frequency is above 99999999Hz, it is displayed in red. Although such frequencies can be set, they appear to be very unstable and may cause the PLL to stop functioning.

In any case, the output buffers will not work well above 100MHz, so we do not recommend that you use such frequencies.

The only conditions that are enforced when you enter the PLL configuration manually are that N is between 1 and 4095, M is between 1 and 511, P is between 1 and 127 and that N is greater than M.

Like with the other configuration screen, once you have set parameters that you are happy with, press the "OK" button to update the output frequency or the "CANCEL" button to return to the previous screen without making any changes.

Using frequency presets

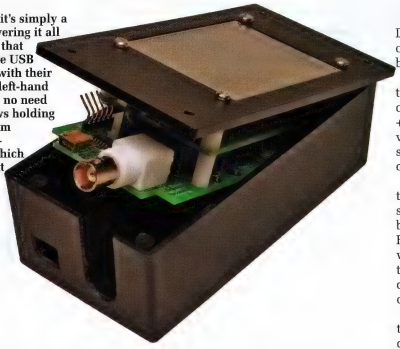
The CON2-CON4 setup pages also show four preset frequencies. They are initially 80MHz, 40MHz, 20MHz and 10MHz (all using a PLL frequency of 160MHz).

The frequency of the output can be changed to any of the presets by pressing that button briefly. Or, to change one of the presets, set the output to the desired frequency and then hold down the preset button for more than one second.

There is also the option to copy presets between the outputs by using the "PRESETS" page, which can be accessed via the "SETTINGS" button on the main page. The preset page has two buttons at the top to allow you to scroll between the various connector presets and output value settings. Their current values are displayed below.

Further down, there is a "COPY" button and a "PASTE" button, followed by the current 'clipboard' values. Pressing the "COPY" button copies the currently selected preset or output value to the clipboard and pressing "PASTE" copies the clipboard value back to the preset or output value. A "BACK" button is provided to return to the main page.

The software will give an error message if you try to copy any setting to



. . . and then it's simply a matter of lowering it all into place so that CON3 and the USB socket mate with their holes on the left-hand end. There is no need for any screws holding the board from underneath – the screws which hold the front panel in place hold the whole assembly snug and secure.

CON4 which is not compatible, ie, it does not have N=4 and M=1.

Additional settings

On the "SETTINGS" page, there are also options to adjust the oven "TEMPERATURE" control loop and the "VCO TRIM" settings. Under the "TEMPERATURE" menu, there are options for Setpoint, Gain and Offset.

The Setpoint is the target temperature of the oven, and as we mentioned earlier, it should be higher than the highest expected ambient temperature where the unit is being used. The default is 35°C, which is suitable either for colder regions or buildings with air conditioning.

The Gain and Offset values are used to change the behaviour of the control loop. It uses simple proportional control and the default values of 1000 for Gain and 3000 for Offset work well. It's unlikely that you would need to change them unless your transistor Q1 has a wildly different gain from the components that we used in our prototypes.

Both values are in DAC step units (out of 4095) with Offset being the DAC output level when the target temperature is reached and Gain being the change in DAC output level for a 1°C error.

If you find that the oven temperature is oscillating wildly, the Gain value should be reduced. A small amount of drift (under 1°C) is to be expected and is not a cause for concern.

If you find that the oven temperature is consistently too high or too low, adjust the Offset value. Allow the unit to settle for about 10 minutes, then check the current DAC output (the number in brackets on the STATUS page) and enter this value as the Offset. You may need to repeat this a few times to get an ideal value.

If you change these values, press the "SAVE" button to store the changes (shown in yellow) or the "BACK" button to go back to the settings screen without making any changes.

Adjusting the VCO control loop

The final settings page is for adjusting the VCO control parameters, which include a "Gain" value, a "C Value" (control value) and the "Update s".

The "Update s" value is the number of 1PPS pulses that are counted before an adjustment is made to the VCO. The default is 1000 but this can be extended to provide further precision, as more 1PPS pulses will be sampled.

The C Value is the current VCO control DAC value (0-16,777,215). This is the value that is changed by the disciplining routine after the correct number of 1PPS pulses have been received.

As such, you should see the value change as this occurs. The default value is chosen to be at the midpoint of the VCO's pulling range.

The Gain value sets the number of DAC steps by which the C Value is changed per Hertz of error, and has been calculated as follows.

The VCO has a pulling range of 0.5 to 2.5V, corresponding to a frequency change of 10ppm (from -5ppm to +5ppm around nominal). The DAC's voltage reference is nominally 2.5V, so the span of the 2.0V pulling range corresponds to 13,421,772 DAC steps.

With a 40MHz nominal frequency, the 10ppm range of variation corresponds to 400Hz. Dividing 13,421,772 by 400 gives 33,554 DAC steps per Hertz, which is our calculated Gain value. Another way to look at this is that each DAC step corresponds to a change of around 30μHz in the VCO output, which gives very fine control.

This is all designed to ensure that the GPS Frequency Reference converges as quickly as possible on the first round of disciplining; given that this process is repeated, the unit is also able to adjust for drift and other factors automatically.

Once again, use the "SAVE" button to commit any changes to flash memory.

Manual VCO calibration

If you have an accurate frequency counter, you can use this to adjust the VCO manually, using the calculations above. If you want to disable automatic adjustment, you can either remove the GPS module or set the VCO "Gain" value to zero. The "C Value" will then remain constant.

To manually trim the VCO, allow the oven temperature to stabilise and set one of the outputs to 40MHz (they are set to this by default in the initial firmware settings). Check the frequency using a precision frequency meter and note the offset in Hertz.

Take this offset, and multiply it by the 33,554 value we calculated earlier, and add (if the current frequency is too low) or subtract (if the frequency is too high) it from the current "C Value".

If there is a small residual error, you can repeat the adjustment to tweak it further.

Conclusion

That completes the construction and set-up of the GPS Frequency Reference.

We are sure that you will find it useful; we certainly plan to make good use of our prototype. SC

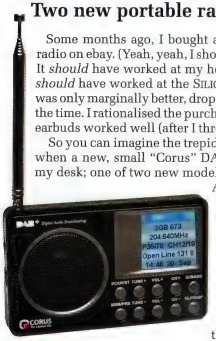
PRODUCT SHOWCASE

Two new portable radios – including a DAB+ that works!

Reviewed by Ross Tester

Some months ago, I bought a tiny portable "DAB+" radio on ebay. (Yeah, yeah, I should have known better!) It *should* have worked at my house . . . but it didn't. It *should* have worked at the SILICON CHIP office. . . but it was only marginally better, dropping out perhaps 80% of the time. I rationalised the purchase by telling myself the earbuds worked well (after I threw the radio in the bin).

So you can imagine the trepidation I felt shortly after, when a new, small "Corus" DAB+ receiver arrived on my desk; one of two new models which Tecsun Radios Australia recently added to their range.



Boy, was I in for a (pleasant!) surprise!

Straight out of the box, it worked brilliantly at SILICON CHIP (an area not renowned for reception!).

It even worked more than acceptably at home (an area renowned for NO reception!).

And, being forced to take a bus from home to work recently, I can report that there were only one or two spots on the 8km journey where it even had a momentary hiccup – this in an area where a normal AM radio also dropped out completely!

Now a bit about the radio: It weighs only 290g and measures just 113 x 69 x 25mm (you'd describe it as "big pocket size"). Unlike my binned receiver, it has an inbuilt speaker (it's also supplied with very comfortable earbuds). It also sports a colour LCD panel to tell you a variety of information about the station you're listening to including the station ID, program type, broadcaster, frequency, channel number, signal strength, volume setting and more.

It has both a DAB+ and FM tuner and you can store up to 30 stations from each band. You might ask why no AM tuner – easily answered by the fact that (I believe) all AM stations in capital cities are also on DAB+. Of course, DAB+ reception is only applicable to capital cities so far; larger regional centres are next on the planning board.

Within the DAB+ band, there is also a host of "extra" special interest stations which you won't find on either the AM or FM bands.

It has a whip antenna (for both DAB+ and FM); when headphones are plugged in their leads also act as an antenna.

An inbuilt rechargeable battery will give up to 18 hours play time and is recharged from any "USB" socket – computer, phone supply, plugpack, etc. One negative I found with this arrangement is that instead of a micro-USB charging socket on the radio, it has a mini DC socket. Admittedly a charging lead is supplied but if you misplace that . . .

The CORUS DTR-762 Portable DAB+/FM Radio is priced at $100 . . . and worth every cent!

Second new model:

The other new model, the Tecsun ICR-110, is a somewhat more conventional AM/FM model. However, its claim to fame is that it not only allows you to record programs off-air to a micro SD (TF) card but it also doubles as a digital audio player, handling MP3, WMA or WAV formats.

At 180 x 110 x 35mm, it's a little larger than the DAB+ model – think more along the lines of a bedside or desktop unit. It sports a rechargeable 18650 battery (a real one, not a fake!) and it too can be charged from a "USB" source. And joy of joys, it has a mini-USB socket on board.

With the exception of the power switch, all controls are push-button.

We've seen this radio on ebay for about $US65.00 (~$AU90.00) – Tecsun Radios Australia's price is better than this at $AU80.00.

If you don't need/can't receive DAB+ in your area, this would be a great choice. And with the jolly fat fella due in just a few weeks, it would of course make an ideal Christmas present.

Contact:
Tecsun Radios Australia
Unit 24, 9 Powells Road, Brookvale NSW 2100
Tel: (02) 9939 4377
Web: www.tecsunradios.com.au

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Unit 17, 69 O'Riordan St Alexandria NSW 2015
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VINTAGE TELEVISION

By Dr Hugo Holden

The 1939 HMV 904 5-inch TV set

This is a most remarkable vintage TV set. Introduced in the UK in 1939, it combined a 5-inch TV set with a 3-band AM radio receiver. It really was a pioneering design and was sold as a "High Definition Television" using the then standard 405-line transmission standard.

The first TV receivers were based on 5-inch cathode ray tubes with electrostatic deflection, as used in oscilloscopes but shortly after BBC TV broadcasts started, this HMV set was introduced with a magnetic deflection yoke. It is very rare. At last count, there were only about 20 to 30 of this set known to remain.

The 405-line standard used a 45MHz amplitude modulated carrier but different to the American system of the time; synchronising pulses reduced the carrier and it increased with the white level. The sound carrier was also AM at 41.5MHz and 6dB down in level with respect to the video carrier.

The English EMI television system specified 25 frames per second, interlaced scan, 405 picture lines, giving a field frequency of 50Hz and line scanning frequency of 10,125Hz. This produced a very audible whistle to anyone with normal hearing, compared to the later 625-line system (as used in Australia) which had a line frequency of 15,625Hz (still audible).

While it may seem like a very big challenge, I found the idea of restoring a 405 line set very appealing, to experience the performance first hand. The more one looks at this unit, the more remarkable it seems.

As already noted, it is also a 6-valve multi-band radio which tunes over 16.5 to 50 metres (short-wave), 200 to 570 metres (medium wave) and 725 to 2000 meters (long-wave) with a very elaborate dial and chain drive vernier scale system.

The local oscillator and audio stages are shared in both the television and radio modes. This is achieved with a fairly complex arrangement of intermediate frequency (IF) transformers, combined multi-coil units and a very elaborate multi-wafer band switch.

The IF transformer coils in the television section have large brass tuning slugs and this technique results in a decrease in inductance of the coils they tune; there are no powdered iron cores or ferromagnetic cores in the inductors of the HMV 904.

As well, the HMV 904 has some unique circuit features which include the vertical output stage, the horizontal line output stage (without a damper diode) and the very impressive "Anode Bend" detector/combined video output stage.

No less than 16 valves are employed. One of the most interesting and beautiful tubes is the converter (V2), an X41C (ceramic base X41), the triode part of which forms the set's local oscillator

The underside of the unrestored HMV 904 chassis with the valves removed. Due to the age of the set, it's no surprise that it had rusted quite significantly.

that runs at 37MHz; below the received carrier frequencies of 41.5MHz (sound) and 45MHz (vision).

Usually, a local oscillator runs the intermediate frequency above the received frequency, but this would have been too high for the X41 which has similar electrical characteristics to an ECH35.

My set was acquired from the Early Television Foundation in the USA. They acquired three, restored one for their collection and then sold the other two; one to me. The set had some fairly severe problems. Firstly, the "Emiscope 3/1" type CRT was missing. There was very extensive chassis corrosion. In fact, everything that was steel had rusted; mechanical parts, screws, bulb sockets small brackets etc.

There was also moderate corrosion on all the aluminum parts. Underneath the chassis, the wiring was disintegrating and in some places the insulation had turned to powder; a reminder of just how old this set was, at almost 80 years!

Every wax-impregnated paper capacitor was leaky, every electrolytic faulty, and the valve sockets were corroded. Some of the resistors were still OK and fortunately all the important parts such as the RF coils, IF transformers and power transformers turned out to be functional but still required restoration.

The main dial was in good order but the round vernier dial was very rusty with flaky paint. The cabinet would require complete refinishing.

The task began with the documentation of the chassis wiring. Due to this set being a TV/multi-band combination, the switching is enormously involved and the wiring and component placing very crowded. It took almost two days to accurately document the wiring in the rotary switch areas and multi-winding coils to ensure an accurate rebuild.

The set was then stripped down completely. The chassis, brackets, multiple rusted mechanical parts, including the variable capacitor frame (from the radio section) and bulb sockets were all fine bead blasted to remove all traces of rust and then electroplated with the process of "electro-less nickel". I have a preference for this because it electroplates into corners and down holes, so it is excellent for complex shaped objects. It has a great satin silver metallic look

The top of the HMV 904 chassis with the IF transformers still in place.

NOTE : To accommodate variations in the magnetic flux of the focus coil it may be necessary to vary the value of R57. Values of 2,500, 3,500, or 5,000 ohms (2 watt) may be used. Do not alter resistance until both positions of the focus adjustment have been tried. It is important that correct focus can be obtained in the first third of the rotation of the "Focus" control (from minimum).

V1—H.F. Amplifier, television and broadcast (M5P4)
V2—Frequency Change ,, ,, ,, (X41C)
V3—I.F. Amplifier ,, ,, ,, (KTZ41)
V4—Sound Detector ,, ,, ,, (MHD4)
V5—Sound Output ,, ,, ,, (KT41)
V6—H.T. Rectifier (U52)
—I.F. Amplifier, television only (KTZ41)
V8—I.F. Amplifier, vision only (KTZ41)
V9—Vision Detector (M5P4B)
V10—Limiter (KTZ63)
V11—Frame Oscillator (KTZ63)
V12—Frame Output (KT63)
V13—Line Oscillator (KTZ63)
V14—Line Output (KT63)
V15—Extra H.T. Rectifier (U17)
V16—Pulse Diode (D42)

VR1—Volume Control
VR2—Contrast ,,
VR3—Brightness ,,
VR4—Width ,,
VR5—Height ,,
VR6—Line Hold ,,
VR7—Frame ,,
VR8—Focus ,,
VR9—Form ,,
VR10—Tone ,,
VR11—Synch. ,,

NOTE : C14 may be made up of two condensers.

FRAME

LINE

to it, resembling the original plating and has excellent longevity.

This can be further improved with a coat of clear lacquer, preferably VHT and oven baked. It was not practical to re-plate the many rusty screws so I obtained new ones of identical geometry and with the original BA threads, which were readily available.

The aluminum components were polished and lacquered for protection. The tube shields, a composite of steel and alloy, were treated with rust converter and ultimately after a lot of preparation, painted with fine silver lacquer. The yoke and focus coil assembly received the same electroplating process but were again painted with black lacquer to match their original finish.

The vernier dial was repaired by first scanning, re-plating and re-painting it. Then I doctored the image in Photo Studio software and printed out a replacement scale to apply to the re-painted dial.

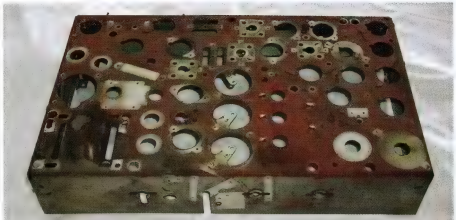
The electrolytic capacitors were replaced and the paper capacitors rebuilt with new caps placed inside and the ends sealed with polyester resin. The large EHT filter capacitor was also re-built. The original valve sockets were all replaced with high-quality vintage ceramic sockets, which after a lot of hunting, turned up in the UK.

Two of the dual-gang concentric shaft potentiometers needed to be manufactured to replace the originals that were totally worn out. It was possible to fit high voltage non-electrolytic capacitors of the same value and higher voltage than the original electrolytic capacitors that lived inside the rectangular can.

These were mounted to a flat PCB to keep them in an orderly configuration. The chokes, transformers and 3-gang tuning capacitor also needed to be restored.

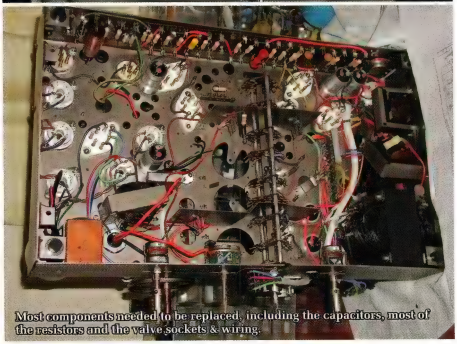
Finally, the set was reassembled with the original under-chassis layout and original tag boards with the rebuilt capacitors and many new resistors too. A few of the original resistors were still OK. A set of NOS tubes, again purchased in the UK, were fitted. The new hookup wire is silicone rubber covered wire which is extremely heat resistant and as it happens, closely resembles the appearance of the original rubber covered wire.

But many challenges still lay ahead, including the electrical alignment of

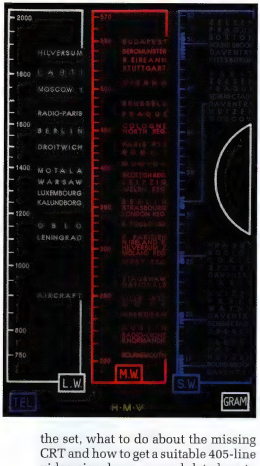


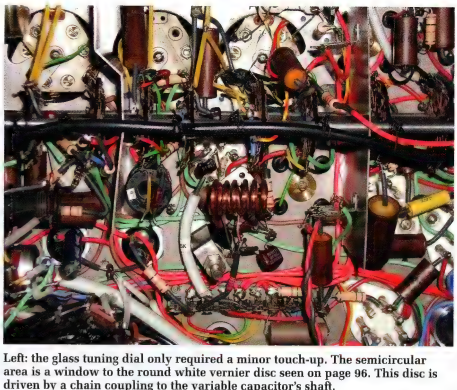
The naked chassis of the HMV 904 had rust over most places and some small burn marks.

After the chassis was cleaned and electroplated, the valve sockets, a few resistors and other components were reinstalled.



Most components needed to be replaced, including the capacitors, most of the resistors and the valve sockets & wiring.





Left: the glass tuning dial only required a minor touch-up. The semicircular area is a window to the round white vernier disc seen on page 96. This disc is driven by a chain coupling to the variable capacitor's shaft.
Above: the copper coil is the tank oscillator coil for the X41C converter valve. Near it, some of the paper capacitors had their insides replaced with newer caps.

the set, what to do about the missing CRT and how to get a suitable 405-line video signal source modulated on to the correct carriers.

Vertical and horizontal output stages

The frame (vertical) deflection yoke in this set has a relatively large number of turns and a high DC resistance of 5kΩ. The output tube's (V12) anode load is a 10kΩ carbon power resistor (R56).

The yoke is coupled to the anode of V12 by an 8μF electrolytic capacitor, C75, and returned to the cathode of V12. So unlike modern magnetic deflection circuits, the load is predominantly resistive; not inductive and reactive.

The anode voltage waveform in this set is nearly perfectly saw-tooth in character to produce a saw-tooth scanning current (when the load is partially reactive the correct drive waveform is trapezoidal, ie, a combination of a saw-tooth and a rectangular wave to result in a saw-tooth scanning current).

While the plate resistor they have used is very inefficient, it does provide a satisfactory degree of damping and doesn't occupy much space. As well, it is an inexpensive option compared to the usual frame (vertical) output transformer.

The line (horizontal) output stage is based on pentodes V13 and V14. The blocking oscillator is configured in the screen grid circuit of V13 and the output derived from the plate to drive V14. Feedback from the output transformer to the oscillator transformer via C85 appears to assist rapid fly-back. The output transformer's iron core can just run satisfactorily at 10,125Hz.

If this line circuit is set to run faster, at 15,625Hz, for example, the linearity suffers badly, with compression of the left side of the raster. The line yoke coils have a very low DC resistance of around 11Ω and represent a very inductive load. There is no damper diode and the damping is merely resistive.

This damping and to a degree the linearity, is adjusted by a control labeled "Form" R9 in the circuit. Despite this, the linearity at the correct scanning frequency is quite acceptable.

A. D. Blumlein

It appears that the first person to postulate the use of the damper diode in 1936, in the UK, was Alan Dower Blumlein, the "inventor" of stereo audio. He patented "binaural audio recording" in 1931. Blumlein was killed in a plane crash in 1942 testing radar. His death was described by Winston Churchill as a national tragedy.

Damper diode function was very well examined by RCA laboratories during the post-war period, in an article by Otto. H. Schade (see references). This article references Blumlein's original patent for a non-linear deflection circuit with diode from 1936.

Over the years, "efficiency diode" or "booster diode" became synonymous with damper diode. In these early years it became obvious that magnetic deflection circuits really only need to be energy control/management systems. In deflecting a beam about centre, no overall energy is required, only enough to overcome losses.

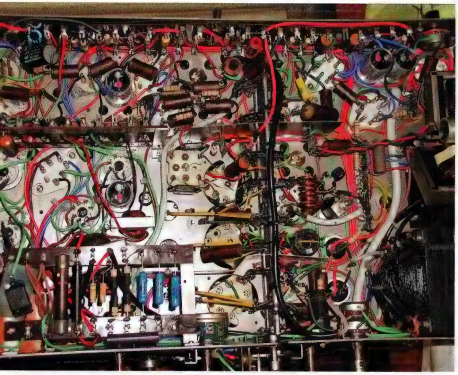
This is analogous to a swinging pendulum, requiring small amounts of additional energy per cycle to keep it going. Despite the early work by Blumlein in the UK, the damper diode concept had not found its way into the HMV 904.

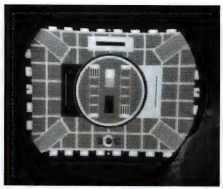
Anode bend detector

Being a combined TV/3-band radio, there are two AM demodulators, one for the radio and TV sound and one for the video detector, based on the MS4B (V9), a metallised glass tetrode.

This is biased as an "Anode Bend" power detector. This is the first time I have encountered this in a television set and is a very good idea. The anode is direct-coupled via inductor L29, capacitor C60 (2μF) and resistor R65 (230kΩ) to the CRT's cathode.

In effect, V9 is biased as a class AB amplifier. As a result, the "no signal"





Above: the underside of the chassis after all parts had been replaced.
Right: two shots from the 5FP4 tube; one of a test pattern from the 625-405 standards converter, and below it, a freeze frame from a PAL camcorder passed through the converter.

plate current is very low compared to its class A counterpart used in most television sets. This avoids power loss in the anode load resistor.

The grid is of V9 is driven directly with the video carrier and the positive half cycles of the carrier are preferentially amplified due to the bias conditions being set for that mode. The carrier is filtered out by L29 and the associated capacity of the components and cathode circuit of the CRT.

Oscilloscope analysis of the detected and amplified video shows it to be excellent, producing 25 to 30V peak-to-peak without any difficulties.

Electrical alignment

Following the manufacturer's advice in the manual, I set up the RF, oscillator and IF stages, first the radio section and then the television section. Due to the sound and vision IF being common, there is interaction between the two and when one is adjusted the other must also be reset.

After completing the alignment I swept the IF response of the set in the usual way, and much to my astonishment found that the intended video IF bandwidth was only 1.4MHz. Despite this, the screen image on the 5-inch tube was just acceptable.

With a few minor adjustments and the use of the sweep generator I was able, without any modifications, to get the bandwidth to 2.4MHz. This substantially improved the picture detail and lowered the overall gain a little but there was plenty of gain to spare.

It also became obvious right away that the magnetically-focused 5FP4 (see text below) is superior to both the electrostatically scanned 5BP4 and 5AP4 employed in USA prewar sets such as the Meissner and Andrea KTE-5 respectively.

The latter tubes tend to lose focus as the beam intensity increases or is varied. This is due to the influence of the grid voltage on the beam and changing relative potential with respect to the focus electrode.

The 5FP4 on the other hand maintains excellent focus at all beam intensities. However, as the set warms up with time, the focus coil current changes a little and requires readjustment with the front panel focus knob from time to time. I don't think constant current sources were on designers' minds back then.

Substitute picture tube

A replacement Emiscope 3/1 CRT could not be found. One fellow in the UK told me he had been looking for one since the late 1950s and had no luck. Some were found later but with fairly low emission which would result in a washed out picture.

Steve McVoy of the Early Television Foundation suggested a 5FP4. This, like the 3/1, is a 5-inch magnetically deflected, magnetically focused tube that was designed post war by RCA for the viewfinder on the TK30 camera.

Significantly, this tube, as per the original is a non-aluminised tube, which is very important with the low EHT voltages. Aluminised CRTs require anode voltages between 5kV and 7kV.

I located some 5FP4s and started testing. The neck on the 5FP4 is a little larger than the Emiscope 3/1, but removal of a small amount of cardboard from the centre of the yoke allowed it to just slip over the neck of a 5FP4. The 5FP4 tube specs suggest a minimum EHT voltage of 4kV but I had no difficulty running it on the 2.4kV in the HMV 904 set.

In the result, I found the 5FP4 makes an excellent substitute, as shown in the un-retouched screen shots of the set working.

405-line video source and standards converter

All of the foregoing work would have been pointless without a source of 405-line video.

The test pattern originates from David Grant's converter board, and is shown on the previous page. The lower photo started out as a freeze

The finished converter built into an OKW case (top lid removed), with the same output signals as the original BBC Alexandra Palace transmitter from 1939.

frame image from a PAL camcorder and was passed through a 625 to 405 video standards converter.

Vintage television collecting is becoming quite popular in the UK and a few talented people have turned their hands to making standards converters. These receive a 625-line video source, basically digitize it, store it in memory and then read it out at the lower 10,125Hz line rate.

I acquired a standards converter as a set of two boards and small motherboard from David Grant in the UK. This converter also has an onboard 405-line test pattern generator.

I designed and built my own modulators modifying some existing Aztec units for crystal control and providing appropriate clamping and polarity inversion for the video. In addition, a mixer amplifier and mini circuits RF attenuator was used to control the RF levels.

This unit effectively recreates the signals generated by the original BBC Alexandra Palace transmitter in London. The unit can provide an RF output of up to 14mV RMS into 75Ω, but in practice 3mV is a suitable level for the HMV 904.

Conclusion

The overall performance of the 904 is very good. The radio section gives excellent performance and the CRT image is quite acceptable, despite the relatively low video bandwidth of 2.4MHz.

This is primarily because the lower resolution is simply not as noticeable on a 5-inch CRT. The benefit of magnetic focus is obvious, so despite the poorer IF bandwidth compared to the US-designed 5-inch Andrea and Meissner 1939 TV sets, the overall picture is comparable over a range of contrast settings on the three sets I have.

The sound on the 904 is very impressive. These pre-war TV sets have a relatively wide bandwidth in the sound channel compared to standard AM transmissions on medium or short-wave.

To me, the audio quality is indistinguishable from the FM sound in modern PAL sets. The effect is enhanced by the usual Class-A audio output stage and good-sized timber cabinet with a permanent magnet 6-inch speaker.

The fully restored unit with replacement tube.

At right is the scanning coil assembly of the yoke, while the diagram on the left shows the full yoke with the focus coil and scanning coils.

I have no doubt that the deflection coil and focus coil assembly and the line output transformer in the 904 would have been more expensive to produce than using electrostatic deflection.

This may have been compensated for a little with the simpler magnetically-deflected CRT. On the other hand, the 5AP4 and 5BP4 CRTs with their more elaborate gun structures probably cost more than the Emiscope 3/1 or the 5FP4 to produce, but likely not by a great deal.

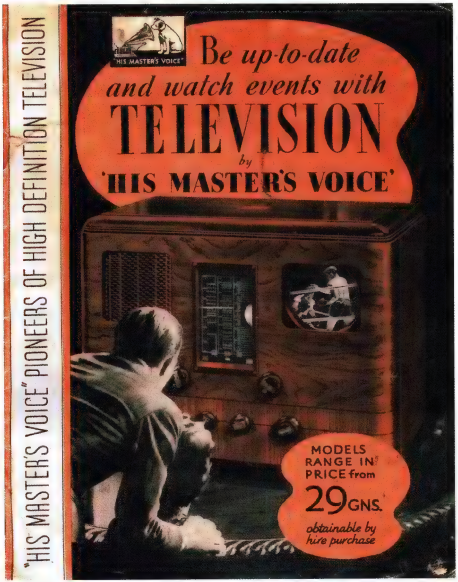
Ultimately, magnetic deflection won out over electrostatic, because larger electrostatic CRTs required very high deflection voltages. With electrostatic deflection, for any deflection voltage, the amount of beam deflection obtained is inversely proportional to the EHT voltage.

In magnetic deflection, for any deflection current, the amount of deflection is inversely proportional to the square root of the EHT voltage. Higher EHT voltages are required for bright high contrast images on larger CRTs and magnetic deflection is more practical for that reason.

Finally, one cannot fail to be impressed by the level that television technology had reached by 1939. Viewing programs on these sets is not a great deal different from observing them on any black and white television manufactured decades later, in the 1950s and 1960s.

In my opinion, the 904 was very advanced for 1939, with its magnetic deflection, magnetic focus and multi-band radio, all amazingly compact for that year.

The Aurora 625:405 line converter is popular in the UK and is used by most TV restorers (David Grant's converter is harder to get).



The "high-definition" HMV 904 cost 29 guineas back in 1939, which would have been very expensive to purchase at the time.

Tips for restoring pitch-coated transformers

The pitch coating on transformers hardens and cracks as it ages. In the case of line output transformers, this can lead to corona discharges and insulation failure. Laminated iron core types often also have a rusty stack.

One way to deal with this is to place the transformer in a bath of mineral turpentine. Over a few days, the pitch dissolves. An occasional gentle stroke from an artists' brush will help this process along.

In the case of a line output transformer, it should then be dried and dipped multiple times in marine spar varnish to build up a thick coat.

In the case of a rusted iron core type, such as a mains transformer or choke, after the pitch has been dissolved, the visible lamination rust can be cleaned off with 800-grit sandpaper.

The stack should then be painted with Fertan (organic rust converter) which leaves a dark blue-black finish on the lamination surfaces, prior to the varnish dip. When the varnish dries it leaves a non-sticky surface and does not attach to dust particles, unlike the pitch.

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❑ Magnetic Deflection Circuits for Cathode-Ray Tubes, by Otto. H. Schade. Television Volume V 1947-1948, RCA Review, Radio Corporation OF America, RCA Laboratories Division, Princeton New Jersey. Pg 105.

❑ Basic Television, Second Edition, Grob. McGraw-Hill Book Company, INC. NY, 1954. pg 48.

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$20 MICROS

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PIC32MX470F512H-120/PT	Micromite PLUS Explore 64 (Aug 16), Micromite Plus LCD BackPack (Nov16)
PIC32MX470F512L-120/PT	Micromite PLUS Explore 100 (Sep-Oct16)
dsPIC33FJ128GP802-I/SP	Digital Audio Signal Generator (Mar-May10), Digital Lighting Cont. (Oct-Dec10) SportSync (May11), Digital Audio Delay (Dec11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)

When ordering, be sure to select BOTH the micro required AND the project for which it must be programmed.

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Explore 100 kit (Cat SC0264; no LCD included) **$15.00/pk.**
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PCB plus all on-board parts including programmed microcontroller (SMD ceramics for 10µF)

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Hard to get parts: DRV8871 IC, SMD 1µF capacitor and 100kΩ potentiometer with detent

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Includes PCB, programmed micro, touchscreen LCD, laser-cut UB3 lid, mounting hardware, SMD Mosfets for PWM backlight control and all other on-board parts

ULTRA LOW VOLTAGE LED FLASHER (CAT SC4125) *(FEB 17)* **$12.50**
kit including PCB and all SMD parts, LDR and blue LED

SC200 AMPLIFIER MODULE (CAT SC4140) *(JAN 17)* **$35.00**
hard-to-get parts: Q8-Q16, D2-D4, 150pF/250V capacitor and five SMD resistors

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WeMos D1 Arduino-compatible boards with WiFi (SEPT17, FEB18):
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1nF 1% MKP (5mm lead spacing) or ceramic capacitor (Wide-Range LC Meter, JUN'17) **$2.50**
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PRINTED CIRCUIT BOARDS

NOTE: The listings below are for the PCB ONLY. If you want a kit, check our store or contact the kit suppliers advertising in this issue. For unusual projects where kits are not available, some have specialised components available – see the list opposite.

NOTE: Not all PCBs are shown here due to space limits but the SILICON CHIP Online Shop has boards going back to 2001 and beyond. For a complete list of available PCBs etc, go to *siliconchip.com.au/shop/8* Prices are PCBs only, NOT COMPLETE KITS!

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
BELLBIRD	DEC 2013	08112131	$10.00
LED Party Strobe (also suits Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender MK2	JAN 2014	01112131	$15.00
LI1 Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
NICAD/NIMH BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTER	APR 2014	07101141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	09106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04105141a/b	$15.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-THEREMIN MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10.00/set
MINI-D AMPLIFIER	SEP 2014	01110141	$5.00
COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (D-I) BOX	OCT 2014	13109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110131	$15.00
DUAL PHANTOM POWER SUPPLY	NOV 2014	18112141	$10.00
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
ONE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TDR DONGLE	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30.00/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015	SC2892	$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	01105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$2.50
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	1510815	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19111151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SIREUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116101/2	$15.00
PRECISION 50/60HZ TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24106161	$5.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
100DB STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORER 64	AUG 2016	07108161	$5.00
CYCLIC DUMMY/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01106161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
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ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50
POOL LAP COUNTER	MAR 2017	19102171	$15.00
STATIONMASTER TRAIN CONTROLLER	MAR 2017	09103171/2	$15.00/set
EFUSE	APR 2017	04102171	$7.50
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6GHz÷1000:1 PRESCALER	MAY 2017	04112162	$7.50
MICROBRIDGE	MAY 2017	24104171	$2.50
MICROMITE LCD BACKPACK V2	MAY 2017	07104171	$7.50
10-OCTAVE STEREO GRAPHIC EQUALISER PCB	JUN 2017	01105171	$12.50
10-OCTAVE STEREO GRAPHIC EQUALISER FRONT PANEL	JUN 2017	01105172	$15.00
10-OCTAVE STEREO GRAPHIC EQUALISER CASE PIECES	JUN 2017	SC4281	$15.00
RAPIDBRAKE	JUL 2017	05105171	$10.00
DELUXE EFUSE	AUG 2017	18106171	$15.00
DELUXE EFUSE UB1 LID	AUG 2017	SC4316	$5.00
MAINS SUPPLY FOR BATTERY VALVES (INC. PANELS)	AUG 2017	18108171-4	$25.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER	SEPT 2017	01108171	$20.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER PANELS	SEPT 2017	01108172/3	$20.00/pair
3-WAY ADJUSTABLE ACTIVE CROSSOVER CASE PIECES	SEPT 2017	SC4403	$15.00
6GHz+ TOUCHSCREEN FREQUENCY COUNTER	OCT 2017	04110171	$10.00
KELVIN THE CRICKET	OCT 2017	08109171	$10.00
6GHz+ FREQUENCY COUNTER CASE PIECES (SET)	DEC 2017	SC4444	$15.00
SUPER-7 SUPERHET AM RADIO PCB	DEC 2017	06111171	$25.00
SUPER-7 SUPERHET AM RADIO CASE PIECES	DEC 2017	SC4464	$25.00
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VINTAGE TV A/V MODULATOR	MAR 2018	02104181	$7.50
AM RADIO TRANSMITTER	MAR 2018	06101181	$7.50
HEATER CONTROLLER	APR 2018	10104181	$10.00
DELUXE FREQUENCY SWITCH	MAY 2018	04104181	$7.50
USB PORT PROTECTOR	MAY 2018	07105181	$2.50
2 x 12V BATTERY BALANCER	MAY 2018	14106181	$2.50
USB FLEXITIMER	JUNE 2018	19106181	$7.50
WIDE-RANGE LC METER	JUNE 2018	04106181	$5.00
WIDE-RANGE LC METER (INCLUDING HEADERS)	JUNE 2018	SC4618	$7.50
WIDE-RANGE LC METER CLEAR CASE PIECES	JUNE 2018	SC4609	$7.50
TEMPERATURE SWITCH MK2	JUNE 2018	05105181	$7.50
LiFePO4 UPS CONTROL BOARD SHIELD	JUNE 2018	11106181	$5.00
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BRAINWAVE MONITOR (EEG)	AUG 2018	03107181	$5.00
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Help fixing shorted SC200 amplifier

I just finished building your SC200 amplifier module from the January-March 2017 issues (siliconchip.com.au/Series/308) but then I had a little accident.

I had everything up and running as far as putting in the fuses and setting quiescent current and DC offset; all good. I then, as per the instruction, decided to re-check the quiescent current after the DC offset adjustment and as I was removing the alligator clip from TP5, I shorted it to the upper left-hand fuse holder and poof, all my efforts up in smoke. Well, not all!

All four of the SMD 100mΩ resistors burnt out, plus the output transistors on the right-hand side of the board and it looks like Q8-Q12 as well! I should have turned the power off before touching the clip! You should have heard my language.

Apart from the above-mentioned parts, are there any other parts that might have been damaged? Do you have a fault-finding document available for a correctly assembled board, or could you provide some advice for checking the remaining parts?

I hope you can help. (M. G., Guanajuato, Mexico)

● You can check the output transistors by measuring the resistance between the emitter and collector pins. Check each pair of pins with both possible probe orientations.

If you get a very low resistance reading (well under 1Ω) with the probes both ways around then the transistor is shorted and will need to be replaced. Otherwise, you may be lucky; it could have survived.

After replacing any obviously blown parts and with power applied to the module (and current-limiting resistors in place), you should also be able to measure approximate 0.6V between the base and emitter for Q13, Q14 (positive probe to base) and Q15 and Q16 (negative probe to base).

If one or more output transistors have gone short circuit, it is possible that Q11 or Q12 could be checked with a multimeter in the same manner as for the output transistors.

In our experience, it is unusual for damage to extend further back than the VAS transistors (Q8/Q9) when there is a short circuit in the output stage.

Having said that, the most common type of short circuit is when the output is shorted to ground.

Accidentally connecting a point in the output stage to a supply rail could possibly cause voltages to flow back into the input stage, damaging other components. The easiest way to check this, after checking and possibly replacing Q8/Q9, is to remove the onboard fuses and apply power to the board via 68Ω 5W safety resistors.

If you get a current draw of up to a few tens of milliamps then it's likely that the front-end is OK and you can then check and if necessary replace Q10-Q16 and any associated failed components (such as the emitter resistors). You can then fit the same 68Ω resistors in place of the fuses and check that the amplifier is working again.

If you run into any problems, the voltages shown on the circuit are the best way to check the amplifier. Measurements taken at these points should be similar on your amplifier.

Trimming current limit on Hybrid SMPS

I have just completed the 40V Compact Hybrid Switchmode 100W Bench Supply described in the April, May and June 2014 issues (siliconchip.com.au/Series/241). I am having trouble with the current limiting section.

During the set-up process described in the June issue, I cannot get VR6 to do anything. Everything else appears to be working as described. Can you tell me what the voltages should be around Q9, Q10, Q14 and Q15? (N. S., Bongaree, Qld)

● First, check that VR2 (current limit) is fully anti-clockwise while adjusting VR6. Measure the voltage between the base of Q9 and GND. It should be very close to 0V with VR2 fully anti-clockwise.

Next, measure the voltage between the base of Q9 and the base of Q10 with VR6 at both extremes. You should be able to adjust the voltage difference over a range of something like ±50mV. Assuming VR6 is adjusting the differential base voltage correctly, check the voltage at the anode of D8 with VR6 at both extremes.

When the base of Q10 is more negative than Q9, the anode of D8 should drop down close to V_{EE}, at around -5V. When the base of Q10 is more positive than Q9, the voltage at the anode of D8 should increase by around 1V, to around -4V.

You could try slightly reducing the value of the 2.2kΩ resistor at the collector of Q20 to see if that helps. For example, connect a 10kΩ resistor in parallel with it using clip leads and see if the extra voltage at the anode of D8 helps it switch on Q25, reducing the output voltage.

Queries on loudspeaker protection circuit

I am currently completing a stereo Class-A power amplifier using your 20W Class-A modules described in the May-August 2007 issues (siliconchip.com.au/Series/58). The recommended preamp has been housed in a separate case with its own power supply.

I want to use your Universal Speaker Protection and Muting Module from July 2007 or the updated version from October 2011 (siliconchip.com.au/Article/1178).

What is the difference between the July 2007 and the updated version of October 2011? There must be some difference. Are you able to tell me which one I should build for my power amplifier?

I will also be running the supply rails at a higher voltage of ±25V DC. I have noticed that the original speaker protection board can take multiple voltages by adjusting the values of R1

and R2. I was looking at changing the values of R1 to 3.3kΩ and R2 to 330Ω for a 25V DC supply rail. Are these values OK? Any assistance would be appreciated. (P. H., via email)

● As indicated in the October 2011 article, both projects use the same PCB but the later circuit omitted four components from the earlier circuit: the second 22kΩ resistor and 47µF NP capacitor from the DC sensing circuits in each channel.

This was done to improve the response time to switch the relay under a fault condition. This was spelt out in detail in a panel on page 37 of the October 2011 issue.

If your amplifier does experience a DC fault, whereby the loudspeakers could have the full DC voltages applied to the voice coils, you want the relay to disconnect the speakers as quickly as possible to give the maximum protection, to remove any risk of damage to the speakers' voice coils or their suspensions.

In your case, you do not have to change R1 or R2 from the values on the circuit. Your 25V supply will result in very close to 24V being applied to the relay coil; the relay is specified to operate at 24V DC. The only reason to change the values of R1 and R2 is to avoid applying excessive DC voltage to the relay's coil.

Explore 100 and Lath-e-Boy mysteries

I am currently building the Lath-e-Boy Lathe controller described in the January 2018 issue (**siliconchip.com.au/Article/10933**), which uses the Explore 100 Micromite module. I have run into a couple of peculiarities when setting it up.

After calibrating the touch sensor on the Explore 100 and then checking it using the GUI TEST TOUCH command, all the dots that result are shown on a vertical line centred horizontally on the screen. In other words, the vertical location of the dots is correct (matching where I am touching) but the horizontal location is wrong.

I tried a second display and got exactly the same result, which makes me think it's a problem with the Micromite. Interestingly, despite the odd behaviour of GUI TEST TOUCH, the touch controls in the Lath-e-Boy software work fine.

When I then run the Lath-e-Boy BASIC code, the Fwd/Off/Rev buttons are about twice the size shown in the magazine.

Amplifier troubleshooting and sourcing low-noise transistors

I have built four Ultra-LD Mk.3 amplifiers (July-September 2011; **siliconchip.com.au/Series/286**), using K5154 kits from Altronics.

Two work fine. One has a bias current which is far too high and the other shows sporadic oscillation. Do you have any suggestions about why this may be the case?

Also, can you recommend an alternative transistor to the now obsolete 2SA970 low-noise PNP device? From a quick glance, the 2N5401 should be reasonably similar. (Anon, via email)

● It would help to know whether the problem with the bias current is that you can't adjust it to a reasonable level no matter what you do, or whether you can adjust it initially and then it drifts up as the amplifier warms.

If the bias current is too high regardless of the setting of trimpot VR1, then you almost certainly have a problem with the construction or a dud component.

With VR1 at its minimum setting, there should be only about 1V between the bases of Q10 and Q11 and that should result in almost no current through the output stage.

If the voltage between the bases is much higher, then something is wrong with Q16 or its associated components. If the voltage is low but the current is still high, then there is a fault in the output stage.

If, on the other hand, the adjustment works normally but the bias current drifts up over time, that's most likely due to variation in the properties of the power transistors (Q12-Q15) or a mismatch in gain with transistor Q16. You could try increasing the value of the 68Ω resistor at the emitter of Q7 to at least 100Ω.

If that doesn't help, try replacing Q16 with a transistor from a different batch (if possible). If that still doesn't work then one or more of the output transistors may be out of spec or badly mismatched.

We haven't heard of oscillation problems with this amplifier. Oscillation with slightly unstable amplifiers typically happens when they are driven into clipping so if it's oscillating with no signal then there is something very wrong.

You could try connecting a 100pF ceramic capacitor from the base of Q8 to the collector of Q9, ie, across the compensation network.

That will greatly increase the amplifier compensation and should make it ultra-stable at the cost of increased distortion. If it still oscillates with that added capacitor, then you have a construction fault or dodgy component.

If that fixes the oscillation, then take a close look at the soldering and components used in the compensation network and make sure everything is correct. If you can't find any problems, try reducing the added capacitor value to around 10-33pF.

If it is stable with a lower value capacitor across the compensation network, that suggests your amplifier is unusually unstable, which may be due to a transistor with unusually high or low gain or another component with a significant variation from its expected value. If the added capacitor stabilises it, we would be inclined to leave it like that, provided you are sure it is not oscillating.

Regarding a substitute for the 2SA970 low-noise PNP transistors used in the input network, that's a tricky one. We have found some SMD devices with similar performance although some of them are already obsolete too. We would not suggest the use of the 2N5401 as its noise performance appears to be significantly worse.

The KSA992 is advertised as a low-noise audio transistor and may be a good substitute but the data sheet gives its noise performance in mV rather than as a noise figure in dB, so it's difficult to make a direct comparison.

I had to modify the code to change the button diameter from 80 to 30 to get them to an appropriate size. Can you throw any light on these problems? (G. C., Mount Dandenong, Vic)

● We haven't heard of that problem with GUI TEST TOUCH. It sounds like a software glitch given that the touch system is apparently working and given that swapping the display didn't fix it (otherwise we would suspect a faulty touch controller on the display).

The button size problem is also quite baffling. Assuming you are using the same resolution display as specified (and we think you are), we can only think of two explanations; either a bug in the BASIC code or a change in the way that MMBasic interprets the GUI commands. Neither seems particularly likely. At least you were able to fix it.

Mysterious error from NFC shield

I am having difficulty getting the Micromite software for the NFC Shield which was mentioned in the September article (siliconchip.com.au/Article/11236) working. I purchased a Deek-Robot device rather than the Arduino shield version described in that article.

I wired the device up as per the Micromite diagram (Fig.3 on page 89) and attempted to run *readMifareTargetID.bas*. I got the following messages:

```
FOUND PN532
FIRMWARE VERSION:1.6
SUPPORTS: 7
SAM Config Failed
```

Thinking that perhaps my device was incompatible with the device in the article, I wired it to an Arduino Uno and discovered that my device worked perfectly with the Arduino software.

I then re-connected it to the Micromite but got the same error message again. I also tried *readMifareMemory.bas* but got the same error message. I then tried *readMifareAllMemoryBlocks.bas* and it worked like a charm.

I then returned to *readMifareTargetID* and *readMifareMemory* and found that they would now work also. But when I removed power and rebooted the Micromite, *readMifareMemory* and *readMifareAllMemoryBlocks* no longer worked and gave the above error.

I then copied the MAINLOOP section of code from *readMifareTargetID.bas* and substituted it for the MAINLOOP code of *readMifareAllMemoryBlocks* and found that it now worked at all times even after a power down. The same procedure also succeeded in getting *readMifareMemory* to work under all conditions.

Do you know why this might be the case? By the way, I really love the section on El Cheapo devices. Please keep the articles coming. (J. H., Nathan, Qld)

● If you copy the main loop from *readMifareTargetID* to *readMifareAllMemoryBlocks*, the only differences between the files will then be some debugging print statements, on lines 213, 216 and 217. These are all in a function which is not called until after the "SAM Config Failed" error message is displayed. So those few

Can the Compact 12V Stereo Amplifier be used in bridge mode?

I have a query regarding the Compact High-Performance 12V 20W Stereo Amplifier you published in the May 2010 issue (siliconchip.com.au/Article/152).

I note that it is still available as a kit from Altronics (K5136). Can it be operated in bridge mode, using the SILICON CHIP Bridge Adaptor For Stereo Power Amplifiers (July 2008; siliconchip.com.au/Article/1887) for a higher mono power output?

For electric guitar use, can this be paired with the 2-channel Guitar Preamplifier (siliconchip.com.au/Series/134) from the November & December 2000 and January 2001 issues? Thanks for your help. (P. B., via email)

● You can't bridge the 12V amplifier described in the May 2010 issue because it already drives the speakers in bridge mode.

The IC contains four separate amplifiers, to drive the two channels in bridge mode in order to obtain the 2x20W power figure despite the low supply voltage.

The only way to get more power is to use a higher supply voltage or a lower impedance loudspeaker. But the maximum supply for that design is 18V and the lowest impedance it supports is 4Ω, giving a practical maximum output of around 30W per channel into 4Ω.

If you must use a DC supply (eg, 12V battery), it can be boosted using a switchmode boost converter, as described in the May 2013 issue ("DC/DC Converter for the CLASSiC-D Amplifier", siliconchip.com.au/Article/3774).

Otherwise, if you're running the amplifier from mains and want more than 20W per channel, we suggest you take a look at the SC200 amplifier design in the January-March 2017 issues (siliconchip.com.au/Series/308). It's a relatively simple and low-cost design that can deliver plenty of power. We can supply the PCBs for that project (including the power supply) and the harder to get parts (see siliconchip.com.au/Shop/?article=10500); the rest are available from Jaycar and/or Altronics.

The CLASSiC-D would also be suitable; it's more efficient but also more complex (November/December 2012; siliconchip.com.au/Series/17). It's available as a kit from both Altronics (siliconchip.com.au/link/aalv) and Jaycar (siliconchip.com.au/link/aalw).

Regarding the preamplifier, yes, you certainly can use a preamplifier with the 12V Mini Stereo Amplifier, you just need to feed the output of the preamplifier into one of its inputs.

Note that we described a complete, high-power PA system with an input suitable for an electric guitar in the December 2013, January 2014 and February 2014 issues.

It's called the PortaPAL-D and combines the aforementioned CLASSiC-D high-efficiency amplifier and boost module with a Li-ion battery pack and charger, along with the guitar preamplifier and twin 200mm coaxial drivers.

You can preview the articles at siliconchip.com.au/Series/177 and note that all the PCBs required for that project are also available from our online shop (see siliconchip.com.au/Shop/8/859).

differences cannot explain the behaviour you've noted.

Could it be that you have some intermittent connections which results in your board working sometimes and failing other times?

We have tested all the supplied BASIC programs extensively on the combination of the Micromite and a Jaycar NFC Shield and have not run into the same error message. So we suspect it may be a problem with your board or the wiring.

Theremin knobs not operating as expected

I just finished assembling the Theremin Synthesiser design from your January 2018 issue (siliconchip.com.au/Article/10931) which I purchased from Jaycar as a kit (Cat KC5537). There's something peculiar with the way the pitch and volume knobs work.

For the pitch knob, there's a midpoint where it switches between producing a higher pitch with my hand close to the antenna and producing a lower pitch with my hand close to the antenna.

Something similar happens with the volume knob. It seems I can have it cut the sound when my hand is close, or have it behave in the opposite way.

This makes it quite tricky to calibrate it to behave normally. Is this the way it's supposed to be or did I mess up something during assembly?

All the test points give normal reading except for the TP5 which reads 0.6V instead of 0.8V. The test point TP9 that gives the reading for the setting of VC2 is coherent with the behaviour of the theremin. Instead of going from 2V to 8.6V from beginning to end, it goes from 8V to 2.6V then to 8V again.

- What you are describing is normal behaviour for this traditional type of Theremin because the adjustments are shifting the frequency of an oscillator which is mixed with another fixed oscillator signal.

When you bring your hand close to the antenna/plate, you are lowering the frequency of that oscillator.

If it is already the lowest of the two, the difference between the frequencies will increase, whereas if it is higher than the other then the difference will decrease. The primary output of the mixer is this difference frequency which then controls the pitch/volume.

Therefore, you will need to carefully adjust these settings so that the pitch increases with your hand close to the antenna and volume decreases with your hand close to the plate. These adjustments may be quite touchy to get right.

Part of the reason for this touchiness is that a wide adjustment range is necessary to compensate for a variety of possible conditions when the unit is in use. For example, it could be used on a metallic or non-metallic surface and the adjustments would need to be quite different.

Studio 350 amplifier questions

I have some questions about the Studio 350 Power Amplifier Module from the January and February 2004 issues (siliconchip.com.au/Series/97). On page 15 of the January 2004 issue, it says that the amplifier could ostensibly drive a 2Ω load but it isn't recommended. If the amp is not driven into clipping and not overheating, can it be damaged on a 2Ω load?

The reason that I ask is that many subwoofers have dual 4Ω voice-coils so, using a single amp, your load impedance can be 2Ω for parallel drive or 8Ω for series drive.

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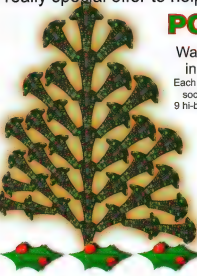

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Remote potentiometer for Full-Wave Motor Speed Controller

I recently purchased the kit for the 10A Full-Wave Motor Speed Controller (Jaycar KC5478) as published in the May 2009 issue (siliconchip.com.au/Article/1434) and I have a question about the 10kΩ speed control potentiometer.

Can the pot be used remotely from the main controller if I use a shielded and Earthed cable and case? I also have a foot pedal with sideways movement of about a quarter of a turn in the pot. Can I use a different pot and resistor values to make this a possibility without using any gearing? (A. W., via email)

● We would not recommend having the control potentiometer mounted separately. The three terminals of the potentiometer are at mains potential and this could be dangerously lethal if the wiring is damaged or if there is a breakdown to the case of the potentiometer.

Nor can you change the potentiometer value because that will prevent the circuit operating correctly.

If you do use an external potentiometer, the potentiometer must be in an Earthed metal box with a 250VAC-rated sheathed cable between the controller and the potentiometer.

You will need a cable with three separately sheathed wires to connect the potentiometer plus an Earth wire with green/yellow striped sheath to join the two Earthed cases together.

The Earth connections should be made using eyelet connectors and M4 screws and nuts with shakeproof (star) washers. The cables must be clamped at the entry holes of the metal boxes using suitable cable glands and clamp to protect the cable from chafing on the metal and also to hold the cables in place.

By the way, these comments also apply to our most recent 230VAC, 10A Full-Wave Universal Motor Speed Controller (March 2018; siliconchip.com.au/Article/10998). This newer design has a simpler circuit and is based on a Triac rather than an IGBT.

But if wired in series, giving an 8Ω impedance, the amplifier usually delivers a lot less power. So I want to use the Studio 350 to drive such a speaker wired in parallel, at 2Ω.

Also, if I decide to use two Studio 350 amplifier modules, would it be better to have each amp drive a separate voice-coil (4Ω each) or bridge the amps and drive the coils in series (ie, 8Ω)?

Will the CLASSiC-D Class-D amplifier drive a 2Ω load? Are there any upgrades in the works to give the CLASSiC-D a higher power output? (J. R., Cambodia)

● The Studio 350 should be fine driving a 2Ω load as long as you avoid clipping and you keep the power level reasonable. To prevent damage, you may want to run it with a lower supply voltage.

The main concern is that at the specified supply voltage, a 2Ω load could easily pull too much current if driven hard. The design features enough output devices connected in parallel to share the current a 2Ω load would draw at moderate power levels.

It wouldn't make a huge difference whether you drive the coils separately using two amplifiers or connect them in series and drive them in bridge mode.

Either way, the amplifiers will "see" a 4Ω load and so the power delivery should be similar. It may be slightly safer to drive them separately in the unlikely event of a fault in one of the amplifiers. You would need a speaker protector anyway.

According to International Rectifier, the CLASSiC-D design as presented cannot handle loads below 4Ω. Even if the Mosfets could handle it, the output filters are not designed to suit such a low impedance.

It may be possible to re-design the filters and tweak other components so that the CLASSiC-D can drive a 2Ω load but at the moment, we do not have any plans to revise it.

Relay sourcing mix-up with LC Meter

I built your Wide-Range LC Meter from the June 2018 issue (siliconchip.com.au/Article/11099) but am having some problems with it. At first, the LCD was blank, but then I read your response on page 106 of the September 2018 issue regarding changing the I²C address to suit the interface module and after following those instructions, the display started working.

I also had problems fitting the instrument into the case and solved them with judicious use of a small file plus different spacers.

But I still can't get any sensible readings from the device. With any capacitor connected, the top line shows 0µF. The display continually changes its mind as to whether it is a capacitor or inductor. The bottom line is blank.

I've checked the soldering and that all the components are in the right location with the correct orientation but I can't find any faults.

The reed relays I purchased have two different markings, even though I got them out of the same bin at the same shop. One is DIR-S8-105A and the other is DIR-S8-105C. I think they are the correct 5V types, based on these markings.

Do you have any suggestions? (A. F., Salamander Bay, NSW)

● You appear to have been supplied with a mix of correct and incorrect relays. The "A" suffix indicates form A (SPST) contacts, which is what you need. The "C" suffix indicates form C (SPDT) contacts. Because pins 1 and 14 are joined on the PCB, these SPDT relays are not able to switch the DUT in and out of circuit, hence the incorrect readings.

We suspect that this was an error by your supplier, who purchased the wrong type of relay and they have become mixed up with their older (correct) stock.

You can make these relays work by cutting off and/or bending up pin 1 of the form C relays, so that it is not making contact with the PCB pad.

CLASSiC-D amplifier module overheats

I have recently built your CLASSiC-D amplifier described in the November and December 2012 issues (siliconchip.com.au/Series/17), from an Altronics K5181 kit. It seems to works well enough, giving a clear output sound with no hiss or hum.

However, it does overheat, even with no signal and regardless of

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whether a speaker is attached. The heatsink temperature climbs steadily to 70°C at around 3°C per minute. The thermal protection then activates and the amplifier cycles on and off about once per minute as the heatsink cools and heats again.

This occurs with the lid off the enclosure and even when the amplifier circuit board is totally removed from the enclosure. My basic understanding is that Class-D amps are supposed to run cool, so this behaviour seems odd to me.

I have checked the component placement and orientation, and checked all the PCB voltages against the instructions. They are within the expected ranges. The supply rails are ±47 V DC. I measured the amplifier gain and it is around 15 times, as expected. Q1 and Q2 appear to be the source of the heat as they are hotter than the heatsink and Q3.

Do you know why it is doing this and how I can solve it? (J. C., via email)

● The most likely scenario is that the amplifier switching frequency is too high and/or the dead time is incorrect, resulting in much greater switching losses than normal.

Check the switching frequency and the components at pins 1, 2 and 4 (which set the frequency) and the dead time setting resistors at pin 9.

Presumably there is no significant DC offset at the output, since you have the speaker protector connected and it would switch the output off if that were the case. So the frequency and dead time are the leading suspects for this overheating problem. SC

Coming up in Silicon Chip

AM/FM/DAB+ Radio with Touchscreen Interface

This is a world-first; a DIY world radio which can receive AM, FM and DAB+ broadcasts. It's controlled using a Micromite Explore 100 module with a 5-inch colour touchscreen and has an on-board amplifier for driving stereo speakers, a headphone output, line outputs and provision for external AM and VHF antennas.

High-Sensitivity Magnetometer

This design uses off-the-shelf components to detect extremely small changes in magnetic field strength. It can be used as a very sensitive metal detector or for a number of other purposes, including moving vehicle detection.

Isolated Serial Link

This small and easy-to-build board provides optical isolation for two devices communicating over a 3.3V or 5V level serial link. It's great for connecting a micro module with a mains or battery power supply to a PC, to prevent power glitches and avoiding damage to the PC from a fault in the connected module.

El Cheapo Modules

The tiny DFPlayer Mini MP3 Player module plays audio files in MP3, WMA and WAV formats from a microSD card or USB flash drive, to either a mono speaker, stereo headphones or line level outputs all for just a few dollars.

Low-voltage, High-current DC Motor Speed Controller

Part two of this series will appear in the December issue. It includes PCB construction and wiring details plus set-up, testing and usage instructions.

Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip.

The December 2018 issue is due on sale in newsagents by Thursday, November 29th. Expect postal delivery of subscription copies in Australia between November 27th and December 12th.

Notes & Errata

Super Digital Sound Effects Module, August & September 2018: in Fig.6 on page 81 of the September issue, the 330kΩ resistor below the 1MΩ resistor next to REG1 is incorrectly labelled as 22kΩ. It is correct in the circuit diagram and on the production PCBs. Also, since publishing these articles, we discovered that there is an alternative version of IC3 (IS31AP4991), the IS31AP4991A. This was not mentioned in the original data sheet and it has a different pinout, so it will not work in our design. Avoid using that chip. Replacement chips have already been sent to those who would have received the incorrect IC from us.

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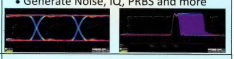
- AM, FM, PM, FSK, ASK, PSK and PWM
- Sweep, Burst and Waveform Combining
- 196 built-in arbitrary waveforms
- Generate Noise, IQ, PRBS and more



SDM3000X

From $595 ex GST

- 4-1/2, 5-1/2 and 6-1/2 digit models
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- True-RMS AC V and AC I measurements
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SPD1168X

- SPD1168X – 128W

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- 1 x 16V/8A with 1mV steps
- High-resolution and high-precision
- 4-wire SENSE compensation mode
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SPD3000X

- SPD3000X – 220W

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- 2 x 32V/3.2A, 1 x 2.5V/3.3V/5V/3.2A
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